PUBLIC HEALTH
LIBRARY

AMERICAN

Industrial Hygiene

ASSOCIATION

Quarterly

VOLUME 16, NUMBER 4
DECEMBER, 1955

LOOK TO DETREX FOR Service WITH A Saving

Value Sign

IN SOLVENT DEGREASING

There are three basic reasons why you get more value in Detrex equipment.

First, no other company can match Detrex experience in solvent degreasing . . . in fact a Detrex development (the art of stabilizing chlorinated solvents) originally made possible modern solvent degreasing. Today, Detrex produces more equipment for use with chlorinated solvents than any other company.

Second, Detrex is the only manufacturer of degreasing equipment who is also a basic producer of solvent . . . industry's *largest* direct supplier of trichlorethylene. Thus, Detrex engineers, chemists, field technicians alike fully understand both the behavior of solvent as well as the operation of the equipment in which it is used.

Third, Detrex service does not stop with installation of equipment but continues, free of charge, for as long as the operation exists. A large, competent staff of Detrex technicians is dedicated to this important work.

All in all, you can't match the benefits that accrue to Detrex customers. And that is the reason why industry prefers equipment that bears the name Detrex . . . it is truly the value sign in solvent degreasing.

DETREX CORPORATION

DEPT. E-311, BOX 501, DETROIT 32, MICH.

AMERICAN

INDUSTRIAL HYGIENE

ASSOCIATION

Quarterly

Volume 16 DECEMBER, 1955 Number 4

THE DETERMINATION OF MERCURY IN URINE—SINGLE EXTRACTION METHOD 275
Evan E. Campbell and Billye Marie Head

COMPARATIVE TOXICITY OF BORANES 280
George J. Levinskas, Ph.D.

SAMPLING AND ANALYSIS OF INDUSTRIAL PROCESS DUST 283
Karl Westlin and Lawrence J. Czerwonka

PARTICULATE ATMOSPHERIC CARBON—A METHOD FOR THE DETERMINATION OF SOURCES 293
George D. Clayton, James R. Arnold and Frank A. Patty

LEAD IN BLOOD—A RAPID METHOD FOR SPECTROCHEMICAL ANALYSIS 296
Kathleen Kumler and Thomas P. Schreiber

A UNIQUE WET COLLECTOR FOR LIGHTWEIGHT AGGREGATE DUSTS 301
Harry E. Seifert and Julius H. Fanney, Jr.

PROBLEMS ASSOCIATED WITH THE APPLICATION OF EXTERNAL AND INTERNAL RADIATION EXPOSURE LIMITS 307
Karl Z. Morgan, Ph.D.

SKIN TESTING OF INDUSTRIAL COMPOUNDS—DEVELOPMENT OF POLYVALENT SENSITIVITY 324
E. von Haam, M.D., and F. S. Mallette, Ph.D.

PRESIDENT'S PAGE 330
N. V. Hendricks

HYGIENIC GUIDE SERIES 331

SELECTED TITLES AND ABSTRACTS FROM FOREIGN EXCHANGE JOURNALS 338

NEWS OF THE LOCAL SECTIONS 339

IN THE NEWS 340

OBITUARIES 340

VOLUME INDEX 341

OFFICERS, DIRECTORS AND COMMITTEES 343

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION QUARTERLY, published by the American Industrial Hygiene Association in March, June, September, and December. HOWARD N. SCHULZ, Editor; HERBERT J. WEBER, Advisory Editor; LLOYD E. GORDON, Associate Editor; JAMES A. MARTIN, Advertising Editor; CHARLES WYMAN, Circulation Editor; A. D. CLOUD, Publisher; DORIS FLOURNOY, Editorial Assistant. Publication and Editorial Offices, 605 North Michigan Avenue, Chicago 11, Illinois. Subscription $4.00 per year in the United States; $4.50 per year in Canada; $5.00 per year in other countries. Single copies, $1.50. Copyright, 1955, the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION. Entered as second class matter May 3, 1948, at the post office at Sheboygan, Wisconsin, under the Act of March 3, 1879. The AMERICAN INDUSTRIAL HYGIENE ASSOCIATION QUARTERLY reserves the right to edit all advertisements and to refuse advertising copy when it does not meet the high professional standards adopted by the Association.

SBS Research Triumph... An Entire

IMPOSSIBLE

UNLIKE ANY OTHER SOAP that is to be used with water, SBS-60 Cream Deodorant Soap is neither a liquid, bar, nor powder . . . but a white, opaque, thick-bodied cream. It is economically dispensed on the hands with no loss and is, for all practical purposes, impossible to waste! The SBS-60 Cream Deodorant Soap dispenser need not be placed over the washbowl or in the shower like liquid or powdered soap equipment. In fact, it can be placed anywhere in the washroom area. SBS-60 Cream Deodorant Soap is pensed on the hands before wetting and may be spread the skin enroute to the washing facility without loss! SBS-60 dispenser can serve many users for both h washing, or showers, with absolute assurance of no s waste . . . no soap spillage . . . no costly dispenser m tenance. Carefully cost-checked, SBS-60 Cream Deodor Soap has achieved savings in soap costs of up to 50% typical plants across the country.

The Determination of Mercury in Urine

—SINGLE EXTRACTION METHOD

EVAN E. CAMPBELL and BILLYE MARIE HEAD, Health Division
Los Alamos Scientific Laboratory of the University of California
Los Alamos, New Mexico

Mercury is determined by the mixed color method using dithizone; interfering elements are eliminated by complexing with versene and by pH control. The published ashing techniques have been studied in conjunction with the single extraction method. Careful oxidation of urine with potassium permanganate and sulfuric acid is recommended. The sensitivity of the method is 1 μg. of mercury with an accuracy of 94.2 ± 4.82%. The advantage of this procedure is the speed of analysis, and purification of the reagents is unnecessary.

MOST OF THE METHODS being used for the determination of mercury, particularly with biological materials, employ dithizone either in the single color or mixed color method of final estimation.[1-5] Each method takes advantage of the acid soluble bromide or thiosulfate complex of mercury for specificity and involves several separatory funnel operations. Vasak and Sedivec[6] used versene (ethylenediamine tetra-acetic acid) to complex interfering substances in their mercury procedure using dithizone and an acetate buffer system, and their findings prompted this study. The use of a single color method would not simplify the method.

The digestion of urines for subsequent mercury determination has been a problem due to the volatility of mercury. Several methods used for removing organic material prior to analysis are not applicable to the digestion of urine for mercury analysis.[7] The volatility of mercury[8,9] precludes the use of dry ashing, perchloric acid oxidation,[10] and nitric acid ashing in an open vessel. Other methods such as catalyzed oxidations cause a high blank and are usually incomplete.[11,12] The use of copper for gathering the mercury is not practical in that copper in the concentration necessary to remove the mercury from urine would interfere with the spectrophotometric method. The aim of this report is to present a simple method and an oxidation technique for urine applicable to the single extraction method for mercury.

The study here presented was made under the auspices of the Atomic Energy Commission.

Equipment

COLEMAN Junior Spectrophotometer; 105 mm cuvettes; Beckman pH meter with standard electrodes.

OXIDATION APPARATUS: 500 ml round-bottomed boiling flask fitted with a dropping funnel and condenser. A "Hot Cone" heater (Central Scientific Equipment Company) was used. See Fig. 1.

Reagents

CARBON TETRACHLORIDE: Analytical reagent.

FIVE PERCENT W/V SODIUM VERSENATE: Disodium ethylenediamine tetra-acetic acid; Bersworth Chemical Company, Framingham, Massachusetts; analytical reagent, 100%. Dissolve 50 g. of sodium versenate in 1 liter of distilled water.

FIVE PERCENT W/V POTASSIUM THIOCYANATE: Analytical reagent. Dissolve 50 g. of KSCN in 1 liter of distilled water.

BUFFER: Citric acid H_2O, analytical reagent; sodium phosphate, dibasic (an-

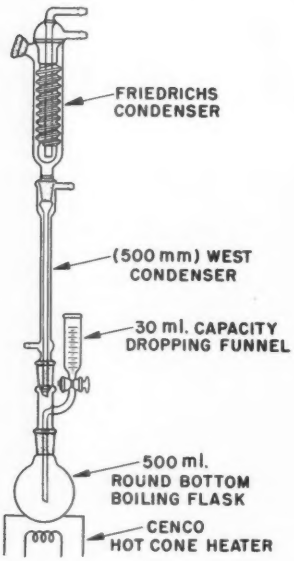

FRIEDRICHS CONDENSER
(500 mm) WEST CONDENSER
30 ml. CAPACITY DROPPING FUNNEL
500 ml. ROUND BOTTOM BOILING FLASK
CENCO HOT CONE HEATER

Fig. 1.
Oxidation apparatus.

hydrous), analytical reagent. Dissolve 178 g. of citric acid and 109 g. of sodium phosphate in 1 liter of distilled water. Ten milliliters of this solution diluted to 100 ml will give a pH of approximately 4.

STOCK DITHIZONE I: Eastman Kodak chemicals. Further purification is unnecessary.[13] Dissolve 500 mg of the dried dithizone in chloroform to make one liter (fresh reagent grade chloroform was found to be suitable for this purpose). This solution will keep refrigerated for several months.

WORKING DITHIZONE II: Dilute 8 ml of the stock dithizone to one liter with reagent grade carbon tetrachloride to give a working solution of 4 mg of dithizone per liter of carbon tetrachloride.

STANDARD MERCURY SOLUTIONS: Dry the mercuric nitrate, analytical reagent grade, at 100°C for 24 hours and allow to cool under desiccation. Dissolve 1.6181 g of the mercuric nitrate in 50 ml of concentrated nitric acid and dilute to one liter with distilled water; 1 ml equals 1 mg of mercury.

WORKING STANDARDS: Make three 1:10 serial dilutions of the standard mercury solution. The acidity of the final solution makes it possible to keep the solution for at least one week; 1 ml of the final dilution will equal 1 μg of mercury.

POTASSIUM PERMANGANATE: Analytical reagent. Several commercial potassium permanganate preparations were used including the pharmaceutical chemical which is a pelleted preparation containing traces of mercury.

TWENTY PERCENT W/V HYDROXYLAMINE SULFATE: Analytical reagent. Dissolve 200 g. of hydroxylamine sulfate in one liter of distilled water.

AMMONIUM HYDROXIDE: Analytical reagent. Sp.Gr. 0.9.

SULFURIC ACID: Analytical reagent. Sp. Gr. 1.84.

Standardization

TO SIX 250 ml separatory funnels add 100 ml of distilled water and 0, 1, 3, 5, and 7 ml of the working standard. These solutions correspond to 0, 1, 3, 5, and 7 μg of mercury per separatory funnel. Add the correct amount of buffer (as determined by titrating a blank solution containing all reagents and a standard of 5 μg of mercury to pH 4),* 5 ml of sodium versenate, 5 ml of potassium thiocyanate, and mix well.** Add 10 ml of the working Dithizone II solution and shake for one minute. Allow the mixture to separate and drain the carbon tetrachloride solution through a cotton pledget into matched 105 mm Coleman cuvettes. Read the percent transmission at 490 mμ,*** using carbon tetrachloride as the 100% reference solution. Plot percent transmission vs. micrograms of mercury on semi-log paper for the standard curve (Fig. 2).

Oxidation Procedure

PLACE 50 ml of urine, or an appropriate volume to contain not more than 14 μg of mercury, in a 500 ml round-bottomed boiling flask with ground glass condenser fittings. Add several boiling chips and 5 g. of potassium permanganate. Allow the solution to stand 15 to 20 minutes so that preliminary oxidation may be completed prior to the sulfuric acid addition. Connect the condenser assembly (Fig. 1) and fill the drop-

*The pH of a series of solutions was checked before and after extraction and in all cases the pH was within the tolerance of pH 4 ± 0.1.

**Mixing all reagents listed and using a single solution proved to have a deleterious effect on the recovery of mercury. The reaction of the buffer, thiocyanate, hydroxylamine, and sodium versenate had a sufficiently slow rate that a freshly prepared mixture was satisfactory. However, a solution so prepared and allowed to stand for 16 hours reduced the recovery of mercury.

***The wave length of 490 mμ on the instrument used produced a standard curve with the greatest slope, even though other wave lengths are linear.

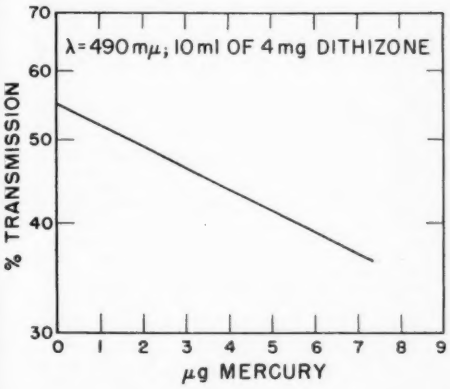


Fig. 2.
Standard curve showing percent transmission vs. concentration.

ping funnel with 10 ml of sulfuric acid. Add the sulfuric acid slowly and swirl the flask. When frothing has ceased, heat and reflux the urine for one hour. After refluxing, add 20% hydroxylamine sulfate either down the condenser or through the funnel until the excess potassium permanganate has been reduced.

Remove the flask and assembly from the heater and allow to cool. (Do not disconnect the condensers.) When the flask is cool enough to prevent boiling of ammonium hydroxide, add concentrated ammonium hydroxide (approximately 20 ml) until a precipitate begins to form but dissolves with swirling. Add sufficient ammonium hydroxide to have a pH not greater than four; excess ammonium hydroxide at this point will reduce the mercury recovery. Allow the flask to cool to room temperature. If a delay is necessary, further addition of ammonium hydroxide should be omitted until an analysis may be carried out. Transfer the contents of the flask to a 250 ml beaker, adjust the pH to 5.5 to 6.5 with ammonium hydroxide using a pH meter, and add the reagents as given in Standardization (5 ml of 5% W/V sodium versenate, 5 ml of 5% W/V potassium thiocyanate), and with the pH meter titrate the solution to a pH of 4 ± 0.1 with the buffer.

CAUTION: *The pH of the solution should be between 5.5 and 6.5 prior to adding the buffer. If the pH exceeds 6.5, adjust to approximately 5.5 with sulfuric acid. A solution of pH below 5.5 should be adjusted slowly with ammonium hydroxide to 5.5 to 6.*

Transfer the contents of the beaker to a 250 ml separatory funnel and continue as given in Standardization with the addition of dithizone.

If a five inch fiber-tipped Beckman electrode is available, the transfer of the reflux flask contents to the beaker is unnecessary. The pH adjustment may be carried out in the flask and the contents transferred directly to the separatory funnel.

Since preliminary estimation is not possible, aliquots should be run so that the mercury concentration falls between 1 μg and 7 μg. If aliquots are not advisable and the dithizone has become saturated, continue adding Dithizone II in 10 ml portions until the carbon tetrachloride retains a greenish color. Use the same standard curve and multiply the micrograms found by the number of 10 ml portions used. No loss in accuracy is observed up to 50 ml of the dithizone solution.

Experimental

EFFECT OF INCREASED VOLUME OF AQUEOUS PHASE ON THE RECOVERY OF MERCURY: It may be necessary to use volumes in excess of the recommended 100 ml in order to have between 1 μg and 7 μg of mercury. Solution volume from 25 to 1000 ml gave good results.

VOLATILITY OF MERCURY: A. K. Klein[9] in a preliminary study showed that mercury would distill from a sulfuric-nitric acid solution. The amounts of mercury found in the distillate from a solution containing 125 μg of mercury was:

Boiling Range	μg of Mercury in Distillate
20 to 120° C	0.0
120 to 130° C	0.9
130 to 166° C	3.0

In order to concentrate urine samples, evaporation was attempted. Water samples of mercury containing 10% sulfuric acid were evaporated on a hot plate. The results of this study are shown in Table I.

It has also been noted that mercury is lost during the addition of ammonium hydroxide to a strong acid solution. When the neutralization is slowly carried out in a reflux system, this loss is minimized. The addi-

TABLE I.
VOLUME REDUCTION AND MERCURY RECOVERY

Original Volume (ml)	Final Volume (ml)	% of 6 μg of Mercury Recovered
100	100*	80
100	75	65
100	50	60
100	25	45
100	Fumes of H_2SO_4	0

*Brought to boiling

tion of sulfuric acid to a potassium permanganate solution may also cause mercury to be lost. When the procedure is carried out as stated, the loss due to volatility is eliminated.

EFFECT OF POSSIBLE INTERFERING IONS ON THE RECOVERY OF MERCURY: Most mercury samples in urine, blood, or air samples (taken by adsorption of the mercury vapor in an I_2-KI solution) are impure. The interference by chlorides, thiosulfate, iodide, phosphate, and hydroxylamine was studied. Chlorides above 50 mg/ 100 ml reduce the mercury recovery because of the formation of mercuric chloride. Normal urinary excretion of 0.01 to 0.03 moles of phosphorous per day in the form of phosphates has had no effect on the recovery of mercury. A 10% loss of mercury was caused by 5 mg of sodium thiosulfate. Up to 25 mg of iodine as sodium iodide will cause no interference. No interference was observed with potassium thiocyanate, hydroxylamine sulfate, versene, and mineral acids. Hydroxylamine hydrochloride added in the form of a solution (10 ml of 10%) reduced the recovery of mercury.

EFFECT OF ACID EXTRACTABLE METAL DITHIZONATES: Palladium, gold, silver, bismuth, and copper interfere with the determination of mercury by dithizone. Palladium was not studied. Bismuth, copper, and to some extent, gold are eliminated in this procedure by the use of sodium versenate. Concentrations of bismuth and copper above 1 mg will interfere. Silver and gold interference is minimized by the addition of the thiocyanate ion. Fifty micrograms of silver and 100 μg of gold cause no error. Even though the complex of silver and gold dithizone forms, the metals may be removed from the carbon tetrachloride by the addition of an excess of thiocyanate. However, sodium versenate will not complex the copper and bismuth once the dithizonate has formed.

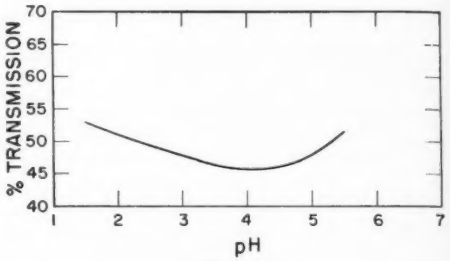


Fig. 3.
Effect of pH on mercury extraction.

EFFECT OF pH ON THE EXTRACTION OF MERCURY WITH DITHIZONE: Mercury is usually extracted with dithizone from a dilute mineral acid solution. The pH meter has been recommended for several reasons. The curve in Fig. 3 shows that the tolerance for pH control is ±0.25 pH. A narrower range is suggested due to the added water during the transfer.

The indicator usually chosen is m-cresol purple. However, at a pH of 4, m-cresol purple prepared as a 2.5% solution in 1:1 ethyl alcohol:water decreases the amount of mercury extracted. Other indicators were not tested because a more critical control of the pH was desired.

OXIDATION OF URINE PRIOR TO MERCURY ANALYSIS: Mercury has been recovered from water samples when refluxed with sulfuric, hydrochloric, nitric, phosphoric and perchloric acids. As previously stated, only such wet ashing procedures involving a reflux type of system appear applicable. Several authors have compared oxidation techniques[7-14] and recommend the permanganate method. A. K. Klein[13] in his final report to the American Association of Official Agricultural Chemists, as a referee for mercury analysis, recommended a modified E. P. Laug and K. W. Nelson method[5] using sulfuric and nitric acid in a Soxhlet apparatus. F. W. Church, as a referee for mercury analysis for the American Conference of Governmental Industrial Hygienists, prefers the potassium permanganate-sulfuric acid technique.[4] Several methods of oxidation were used in this study and are briefly tabulated in Table II.

Accuracy and Precision of the Method

THE ACCURACY of the method is 94.2 ± 4.82% based on the analysis of 75 spiked

TABLE II.
OXIDATION TECHNIQUES OF URINE UNDER REFLUX

	Oxidant Used	Urine Volume (ml)	μg Added	μg Found	Comments
I	Potassium persulfate (solid), sulfuric acid. 5 g. $K_2S_2O_8$:	50	6	0	The persulfate prevented the extraction of mercury and was difficult to remove.
II	10 ml H_2SO_4. Sulfuric acid; hydrogen peroxide was added dropwise until the urine was clear. 10 ml H_2SO_4: 30% H_2O_2.	50	6	0 0 1.8 2.	The urine was never found to be free of organic material. Prolonged heating and H_2O_2 treatment caused the urine to become yellow again.
III	Digestion mixture, 15 ml 1 part $HClO_4$: 3 parts HNO_3: 1 part H_2SO_4.	50	6	0	Ineffective oxidation occurs in the diluted acids and the remaining organic matter retained the mercury.
IV	Laug's digestion mixture;[5] 20 ml. 1:1 HNO_3: H_2SO_4; direct reflux.	50	6	0	Refluxing the urine for as long as 48 hours gave poor results. This has been attributed to the fact that only a single extraction of dithizone was used.
V	Ammonium nitrate sulfuric acid 5 g. NH_4NO_3: 10 ml H_2SO_4.	50	6	0	Same as II. The urine cleared but still had the odor of urine.
VI	Potassium permanganate, sulfuric acid 5 g. $KMnO_4$: 10 ml H_2SO_4.	50	6	5.75 5.5 5.2 5.1	The conditions were controlled according to the procedure and the μg of mercury found excludes the urine and reagent blank. Average loss 0.6 g. or 10%.
VII	Potassium permanganate, nitric acid 5 g. $KMnO_4$: 10 ml HNO_3.	50	6	5.73 5.6 6.4 5.4	Removal of the excess nitric acid was incomplete in a large number of analyses.
VIII	Laug's digestion mixture and procedure of refluxing.[5]	50	6	0.1	The time required to insure complete oxidation is inconsistent. Removal of excess nitric acid is not always complete.

urine samples taken from pooled urine. The pooled urine contained 0.008 mg of mercury per liter. The 50 to 100 ml of urine analyzed was "spiked" with 3 to 20 μg of mercury.

Comments

THE ACCURACY of the method is dependent on the strictness of adherence to procedure. The method is simple and is well within the sensitivity necessary for analyzing the urine of workers exposed to mercury and its compounds. The use of sodium versenate and thiocyanate insures specificity in the final determination. Reversion analysis seemed impractical in view of the results of the direct mixed color method.

The substitution of β-naphthyl thiocarbazone for dithizone has proved unsatisfactory in the single extraction method. Ammonium hydroxide and citrate-phosphate buffers reduce the mercury recovery. Copper, silver, and gold are serious interfering elements even though an excess of versene and thiocyanate have been added.

The techniques and conditions have been established to make the method approximately 96 ± 6% accurate when known or low concentrations of interfering elements are present. β-DN methods cannot be followed by reversion analysis without loss of precision. The purification steps to remove interfering elements described by Hubbard[15] may be somewhat simplified by the use of versene.

References

1. WINKLER, W. O.: *J. Assoc. Offic. Agr. Chemists*, 22:310, 1940.
2. WINKLER, W. O.: *N. Y. State Dept. Labor, Monthly Rev., Div. Ind. Hyg. and Safety Standards, No. 2*, 27, 1948.
3. KOZELKA, F. L.: *Ind. Eng. Chem. Anal. Ed.*, 19:494, 1947.
4. CHURCH, F. W.: *Referee, Standard Method, Am. Conf. Gov't Ind. Hygienists*, Accepted September 11, 1951.
5. LAUG, E. P. and K. W. NELSON: *J. Assoc. Offic. Agr. Chemists, No. 2*, 25:399, 1942.
6. VASAK, V. and SEDIVEC, V.: *Collection Czechoslav. Chem. Communs.*, 15:1076, 1951.
7. VASILEVA, A. A. and M. D. SHAIKOVA: *Aptechnoe Delo*, 2:46-49, 1953.
8. NOYES, A. A. and BAY, W. C.: *J. Am. Chem. Soc.*, 29:1, 1907.
9. KLEIN, A. K.: *J. Assoc. Offic. Agr. Chemists*, 33:594, 1950.
10. SMITH, G. F.: *Anal. Chim. Acta*, 8:397, 1953.
11. MEARS, B. and HOSSEY, R. E.: *J. Ind. Eng. Chem.*, 13:1054, 1921.
12. PARKER, J. G. and TERRELL, J. T.: *J. Soc. Leather Trades' Chemists*, 5:380, 1921.
13. KLEIN, A. K.: *J. Assoc. Offic. Agr. Chemists*, 35:537, 1952.
14. TROITSKII, A. A.: *Gigiena i Sanit.*, 4:51, 1953.
15. HUBBARD, DONALD M.: *Ind. Eng. Chem. Anal. Ed.*, 12:768, 1940.

Comparative Toxicity of Boranes

GEORGE J. LEVINSKAS, Ph.D.
Department of Occupational Health, Graduate School of Public Health
University of Pittsburgh, Pittsburgh

The acute toxicity of dimethylamine-borane, together with the acute toxicity of pyridine-borane and trimethylamine-borane, are reported. On a weight basis, the order of toxicity was found to be dimethylamine-pyridine-trimethylamine-borane. However, when expressed in terms of mgB/kg, the LD_{50} values form two distinct groups. Recalculation of available toxicity data for other boranes enables them to be classified in the same system.

THE PRESENT report began with toxicity investigations of some amine-boranes. Toxicity data for three of these compounds: dimethylamine-, pyridine-, and trimethylamine-borane are presented and an attempt is made to correlate these findings with the toxicity of the boron hydrides.

Formulae and melting points for the three amine-boranes are given in Table I.

The first compound (DMAB) is moderately soluble in water and was administered to animals in physiological saline solutions. The second (PB) is only sparingly water soluble but soluble in propylene glycol. Consequently, this glycol was used as a diluent. Since the third compound (TMAB) is also sparingly water soluble, and not appreciably soluble in propylene glycol, it was first dissolved in a small volume of dioxane and then diluted with water to a volume suitable for administration to the animals.

Adult (200-280 gms in weight), CFW rats, previously fasted for 18 hours, were dosed at four different levels. The LD_{50} values were calculated by the moving average method of Thompson.[2] The results of intraperitoneal injection are shown in Table II.

Presentation of the LD_{50} data either in terms of mg/kg or millimoles/kg reveals a rather sharp division between the first two compounds and the trimethylamine-borane. This was somewhat surprising as the injury to the cells at the ultimate site of action within the body is proportional, not to the number of grams, but rather to the number of molecules which reach that site. We had assumed that the "toxiphore," i.e., the portion of the molecule in which the toxic properties of these compounds resided, was the functional group—BH_3. Such an assumption had enabled prediction of the toxicity of the pyridine-borane from the results of the dimethylamine-borane study, but it had failed with respect to trimethylamine-borane.

Out of curiosity, the LD_{50} values were recalculated in terms of mg B/kg for these compounds. At the same time, a review of the available toxicity data for other boranes was undertaken. Two difficulties were encountered. First, the amount of information in the literature on the toxicity of the boranes is meager. Second, it is not always possible to make comparisons of existing data as the methods of treatment have not always been similar. As an illustration of the latter problem, the boron hydride diborane (B_2H_6)[3] exists as a gas at normal tem-

TABLE I.
FORMULAE AND MELTING POINTS OF AMINE-BORANES

Compound	Abbreviation	Formula	M.P. (°C)	Physical State at Room Temp.
Dimethylamine-borane	DMAB	$(CH_3)_2$ NH. BH_3	35.5-36.0	white crystalline solid
Pyridine-borane	PB	C_5H_5N. BH_3	10.0-11.0	clear liquid
Trimethylamine-borane	TMAB	$(CH_3)_3$ N. BH_3	94.0-94.5	white crystalline solid

TABLE II.
ACUTE TOXICITY OF AMINE-BORANES. INTRAPERITONEAL INJECTION

Compound	Sex and Number of Rats per Dose Level		24 hour LD_{50} mg/kg	mM/kg
DMAB	M	(10)	50.5	0.86
	F	(5)	39.0	0.66
PB	M	(10)	73.6	0.79
	F	(5)	64.8	0.70
TMAB	M	(10)	175.5*	2.41*

*48 hour LD_{50}

TABLE III.
COMPARATIVE TOXICITY OF BORANES—MALE RATS INTRAPERITONEAL INJECTION

Compound	LD_{50} mM/kg	mg B/kg
I DMAB	0.86	9.3
PB	0.79	8.6
B_5H_9 (Mineral Oil Solution)	0.40	9.5
II TMAB	2.41	26.
$B_{10}H_{14}$ (Agar-Saline Suspension)	0.22	24.
$B_{10}H_{14}$ (Mineral Oil Solution)	0.21	23.

TABLE IV.
ACUTE ORAL TOXICITY OF BORANES—MALE RATS

Compound	LD_{50} mg/kg	mM/kg	mgB/kg
I DMAB	59.2	1.00	11
PB	95.4	1.03	11
II $B_{10}H_{14}$	64.3	0.53	57

peratures and pressures. Consequently, no data for oral or parenteral dosage are to be found. Though the number of compounds for which toxicity data are available and comparable is limited,[4,5] an interesting correlation was observed as shown in Table III.

While expressions of millimolar toxicity do not allow for ready classification of the data, expressing the LD_{50} values in terms of mg B/kg effects a general separation of the data into two groups. Comparison of the toxicities based on the boron content of these compounds reveals that the lower group is approximately half as toxic as the upper one. In the upper group (I), we find that a mineral oil solution of pentaborane resembles the dimethylamine- and pyridine-boranes. The lower group (II) consists of trimethylamine-borane and decaborane. It is interesting to observe that the agar-saline suspension and the mineral oil solution of the decaborane are not appreciably

TABLE V.
FOUR HOUR LC_{50} VALUES FOR BORANES

Species	Group	Compound	LC_{50} ppm	mg/1	mM/1	mg B/1
Rat	I	B_2H_6	39	0.045	0.0016	0.035
		B_5H_9*	18	0.047	0.00074	0.040
	II	$B_{10}H_{14}$	(95)	(0.48)	(0.0039)	(0.42)
Mouse	I	B_2H_6	30	0.034	0.0012	0.027
		B_5H_9*	11	0.028	0.00045	0.024
	II	$B_{10}H_{14}$	31 (26-37)	0.16	0.0013	0.137

*Two hour exposure, followed by two hour observation

different in toxicity. Consequently, it appears that neither of these vehicles exerts any marked influence on the results.

Oral LD_{50} values have been determined for only a few of these compounds. The available figures support the same classification (Table IV) in that a sharp division is again observed.

In addition to the comparisons for parenteral and oral dosages, the acute inhalation toxicity was reevaluated as shown in Table V. A similar division is also evident for the LC_{50} values.[6,7]

The parentheses around the decaborane figures given for rats indicate that no animals died after a four hour exposure to this concentration. Consequently, the LC_{50} value would have to be in excess of this figure. For mice, the decaborane figure is calculated on the basis of 31 ppm, an average of the reported range.

This table reveals three points. First, mice are more sensitive to the boranes than rats. Secondly, diborane (B_2H_6), which is a gas, resembles pentaborane (B_5H_9), which is a liquid at room temperature. Pentaborane was shown to fall into group I (Table III) for intraperitoneal dosage and thus serves to bridge the gap between parenteral and inhalation toxicities. The third observation we can make is that there is a correlation between the toxicity and the boron content of the inhaled atmosphere for the two members of the first group which sets them apart from the single member of the second group.

These observations permit some interesting speculation. It can be assumed that the oral and intraperitoneal toxicity of diborane would resemble that of other members of group I. Therefore by extrapolation, LD_{50} values of 14 mg/kg and 11 mg/kg for

oral and intraperitoneal dosage can be calculated. Unfortunately, because of its reactivity, it has not been possible to "trap" diborane in an inert solvent.

Similar reasoning should enable calculation of LC_{50} values for compounds such as dimethylamine-borane. For rats, the figure should be 87 ppm. Attempts to verify this experimentally have been unsuccessful in that we have been unable to achieve these concentrations for any length of time. However, since mice appear to be more sensitive, an LC_{50} value of 54 ppm has been calculated, we propose to pursue further studies on this animal.

While the number of compounds on which these observations are based is admittedly small, the tendency for the toxicity values, when expressed in terms of mg B/kg or mg B/1 of inhaled air, to form two distinct groups is interesting. If this is a reflection of different metabolic pathways through which each group exerts its toxic effect, it challenges the assumption that all boron compounds have the same mechanism of toxicity.

Additional work, to expand the number of compounds tested as well as the variety of conditions under which they are applied, is contemplated to observe whether this classification is a reliable one.

Bibliography

1. Research Associate, Department of Occupational Health, Graduate School of Public Health, University of Pittsburgh.
2. THOMPSON, W. R.: *Bact. Rev.*, 11:115, 1947.
3. WEBSTER, S. H.: *J. Indust. Hyg. and Toxicol.*, 28:167, 1946.
4. SVIRBELY, J. L.: *AMA Arch. of Indust. Health*, 11:132, 1955.
5. KRANTZ, J. C., JR.: Private communication.
6. LAWSON, L., and JACOBSON, K.: Private communication.
7. SVIRBELY, J. L.: *AMA Arch. of Indust. Hyg. and Occ. Med.*, 10:298, 1954.

Industrial Associates

THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION has created several new classes of membership. One of the classes is that of Industrial Associate. The Board of Directors may approve as Industrial Associates such organizations as may apply for this status. These organizations by applying for membership indicate an active interest in industrial hygiene and support of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION. The first applicant for this class of membership is Employers Mutuals of Wausau.

Course at New York University

THE INSTITUTE of Industrial Medicine of the Post-Graduate Medical School of the New York University-Bellevue Medical Center in cooperation with the U. S. Atomic Energy Commission and the New York University College of Engineering is offering a course in radiological safety starting January 9, 1956, and continuing through January 20. A laboratory course will be held through February 3, 1956. The radiological safety courses will be repeated from February through May on a one meeting per week basis. Tuition for each course is $60.00. The radiological safety course has been designed to acquaint technical people with the fundamentals of radiation safety. Additional information concerning the course and application blanks may be obtained from the Office of the Dean, New York University Post-Graduate Medical School, 550 First Avenue, New York 16, N. Y.

Sampling and Analysis OF INDUSTRIAL PROCESS DUST

KARL WESTLIN, Research Engineer
LAWRENCE J. CZERWONKA, Research Physicist
American Air Filter Company, Louisville, Kentucky

This article describes a technique devised to overcome the shortcomings of the various conventional field-sampling methods. It is especially applicable where analysis of the character of sub-sieve-size dust particles in hot or moist gases is involved. A particle size analysis technique is also described that has been found most suitable for process dust studies.

THERE ARE two reasons for the sampling of any dust-laden gas stream: to determine the dust concentration in that stream, and to determine the character of the dust. The dust control industry is constantly faced with the necessity of making these determinations with process dusts of sizes and size-distribution ranges of from a few tenths of a micron to pebble-size and of making these measurements quickly and accurately. Of the many techniques that have been tried in the past for accomplishing these determinations, none have satisfactorily fulfilled both requirements, at least not simultaneously or without undue complications. The necessity for improvement of methods has fostered, not invention in this case, but the improvisation of a workable solution to the problem. Certainly, no portion of the techniques that have been developed and are discussed here are very novel; however, it is felt that the techniques as a whole are unique in that they do provide, first, a method for obtaining a single accurate sample suitable for both dust concentration determination and dust analysis, and further, a method for accurate analysis of this dust sample.

Dust Sampling

THE SAMPLING TECHNIQUE, as discussed here, follows the usual procedure for such a process, with extra emphasis being placed on obtaining a single sample suitable for the two objectives, dust concentration determination and dust analysis. This is just another way of saying that along with being exact in quality, the dust sample must be of sufficient quantity, not only for accurate weighing, but for accurate chemical and particle size analysis as well. Because of the wide variation in particle sizes encountered in process dust studies, samples of at least five grams of material have been considered necessary for proper size analysis.

The weakest "link" in the sampling "chain" has been in the filtering media. Choosing a means for catching the dust became, therefore, the first step in developing the method. The dust collector, to fulfill the requirements, had to be an absolute filter (a collector of effectively 100% collection efficiency) that would remain so under a wide range of operating conditions; it was required that it should maintain its collecting efficiency and physical strength under conditions of extreme heat and/or moisture; it should be easily weighable for concentration determination; it should be possible to remove the collected material from the filter for analysis without danger of adding contaminate to the catch that would interfere with the analysis; and finally, for the sake of a simpler air mover, it should have a low resistance to air flow. These requirements caused the elimination of most of the usual filter methods for various reasons, such as the following:

The various woven (fabric, glass, or plastic) filters were eliminated either because

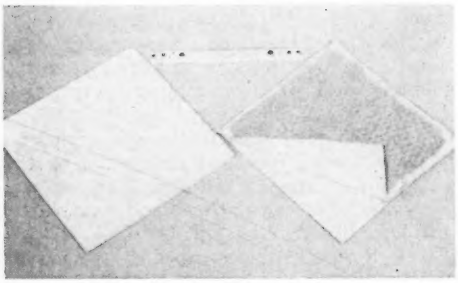


Fig. 3.
AA fiber-glass filterdown sampling media (showing typical penetration of material caught in sampling pad).

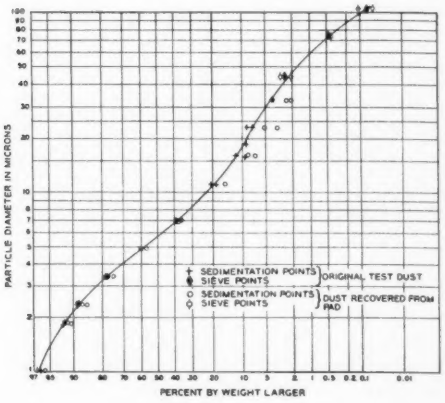


Fig. 4.
Particle size analysis of E-III Alumina L dust.

that is, dusts in which the particles were comparatively spherical and of uniform density. Dust which had particles of widely varying shape and densities could only be analyzed in terms of the equivalent "regular" dust. A factor in favor of the method used was that it permitted analysis of samples as small as five grams in weight.

Procedure for Washing Filter Pads: The first step in the method was the recovery of dust from the filter pad used in the field test sampler. The pads were cut into segments as a matter of convenience. The soiled surface of each segment was stripped, or peeled, from the bulk of the pad, (the dust collected by the ½-inch thick filter was generally retained on the first ⅛-inch to ¼-inch of thickness), Fig. 3. The soiled ⅛-inch to ¼-inch thickness was placed, soiled face up, on a flat piece of metal. Distilled water or a suitable liquid in which the dust was not soluble, was then sprayed against the soiled surface of the pad as a means for producing a mining action which caused the imbedded dust particles to rise to the surface and flow from the pad. As the liquid flowed from the pad it was passed through a No. 325 mesh (44 micron) sieve to retain any broken glass fibers and dust particles greater than 44 microns in size. After the pads had been washed (approximately 1 to 2 gallons of liquid were required to remove the dust from a 12-inch by 12-inch pad) the material retained on the sieve was again suspended in water and then mixed in a blender to put the particles and glass fibers in suspension. The glass fibers were of a needle-like structure, approximately one micron in diameter and more than 44 microns in length. They remained in suspension for an appreciably longer period of time than the more regularly shaped dust particles, and could be removed from the suspension by siphoning after a short sedimentation period. The remaining dust particles were then dried and used for sieve analysis.

Sieve Procedure: If an appreciable portion of the dust (5% or more) was retained on the 44 micron sieve after the pad washing procedure, it was dried and then dry sieved for 10 minutes on a mechanical shaker, through a series of sieves ranging from 840 microns down to 44 microns. This combination of wet and dry sieve procedures was essentially a variation of ASTM wet and dry sieve procedure.[10] The fractions remaining on each screen were weighed and a plot of particle size vs. "percentage-greater-than" size was made on log probability paper (Fig. 4). The "percentage-greater-than" size was based on the total amount of dust recovered from the filter pad.

The above sieve procedure was chosen after trial of several procedures, because it appeared that the results obtained were the most accurate and most easily reproduced. For example, it was found that dry sieving alone showed variable results with fine or sticky dusts because of balling on the sieve surfaces.

The material used for sieve analysis was

recombined with the material which passed the 44 micron sieve in the washing process, and the excess wash water was removed by first allowing the dust particles to settle in a shallow vessel, and then siphoning the clear liquid from the suspension. The dust remaining in the liquid was then prepared for sedimentation analysis.

Dust Dispersion: Up to this step in the procedure only water suspensions have been mentioned. Solubility of the dust in water, however, or inability to disperse flocs in water often necessitated the use of other suspension liquids, and usually the use of dispersing agents. Alcohol, xylene, mineral oil, ethylene glycol, kerosene, and gasoline are examples of the many liquids that have been employed by various investigators for specific dust-suspension problems. Dispersing, or peptizing, agents such as sodium metasilicate, Daoxad, and lignum compounds such as Marasperse C, CB, and N have been added to promote complete deflocculation of the particles so that they would fall as individual particles in the suspension, and not as flocs. Of course, there could be no chemical reaction between the dispersing agent and either the dust or the liquid.

It must be noted here that the dispersing agent seldom broke up the flocculated particles by itself. It only acted to keep the particles separated once the flocs had been broken. The actual break-up of flocs was accomplished by a mechanical blender, such as a malted milk mixer.

Pipette Procedure: After the suspension was completely deflocculated and thoroughly mixed, it was poured into the cylinder of the Andreasen pipette and the liquid volume increased to 550 ml. (to the zero line on the pipette cylinder). The assembled pipette was in turn placed in a thermostatically controlled water bath, Fig. 5. The constant temperature bath insured a constant liquid viscosity and density, and minimized any convection currents in the suspension.

The pipette was arranged so that 10 ml. samples could be drawn at intervals from a point originally 20 cm. below the surface of the suspension. These samples were dried and weighed. Each sample contained dust of the same size frequency distribution as the original, except all particles larger than

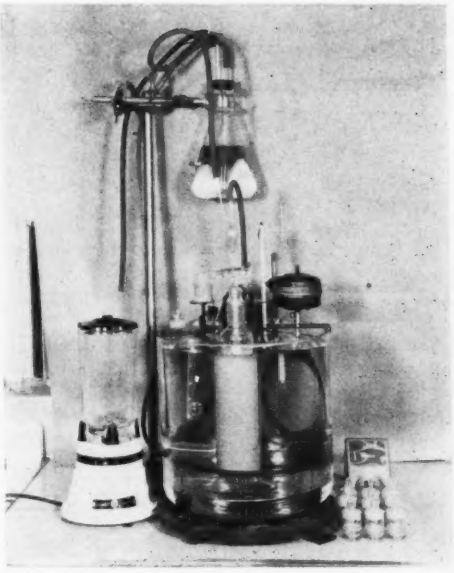


Fig. 5.
Andreasen sedimentation apparatus.

the size being measured had settled out, according to Stokes' Law:

$$d = \sqrt{\frac{18\ nh10^8}{(D_1 - D_2)gt}}$$

where d = diameter of equivalent spherical particle (microns).
n = absolute viscosity (poises) of suspending medium.
h = distance (cm) between liquid level and point at which measurements are made.
t = time in seconds from start of test.
D_1 = absolute density of particles (gm/cm^3).
D_2 = absolute density of suspending medium (gm/cm^3).
g = gravitational constant (980 cm/sec^2).

For irregular particles, d is the diameter of a sphere that falls at the same rate as the particle. The upper limit of sedimentation methods is, in general, 75 to 90 microns. This is controlled by the applicability of Stokes' Law for a Reynolds' number of less than one. The lower limit is controlled by the speed with which results are desired, but is, in general, about 0.5 to 1 micron. There is a greater proba-

bility of error for particles smaller than 1 micron due to Brownian movement and convection currents.

The liquid viscosity and density of dust and liquid used to calculate the Stokes' diameter were determined by standard procedure.[11,12] The total amount of dust recovered from the sampling pad, and used for sieve and sedimentation analysis, was determined after the sedimentation analysis was completed by evaporating the remaining pipette content, summing this weight and the weight of the 10 ml. dried samples, and deducting the weight of the dispersing agent. The percent, by weight, of each 10 ml. pipette sample and the amount retained on each sieve was determined from the total weight. A plot was made on log probability paper of percentage greater vs. particle size (Fig. 4). If the dust was fairly regular in size-distribution, shape, and density a smooth curve would result from combining the sieve and sedimentation analyses.

Method Evaluation: A series of particle size analysis tests were made of dust recovered from the sampler pads by the spray washing process to evaluate the effect of the small amount of glass fibers which could have passed the 44 micron sieve, and further, to determine the amount of dust which had to be recovered from the pad to yield a representative particle size distribution.

Results of duplicate particle size analyses by the combined sieve and sedimentation methods using a Norton Company abrasive (E-111 Alumina L) as a standard test dust are shown in Table I and in Fig. 4. A number of tests were also made in which 10 gram samples of the same dust were aspirated directly into the filter pads contained in the described samplers. This aspiration of dust directly into the pads was done in order to eliminate any possible distortion due to dust sampling procedure. The dust was recovered from the pads by the spray washing process using distilled water as the wash liquid and Marasperse N as the dispersing agent. The data thus obtained were treated in the same manner as that of the original data and are also shown in Table 1 and Fig. 4.

Comparison of analyses of the original dust and the dust recovered from the filter pads showed good agreement when over 70% of the 10 grams of dust was recovered from the pads. If, however, less than that amount was recovered, the dust appeared to be smaller than it actually was. There were slight distortions in the larger size range indicating, perhaps, that a more viscous

TABLE I.
SIEVE AND SEDIMENTATION ANALYSIS

Apparatus: Andreasen Sedimentation Pipette, Set of U. S. Sieves.
Material: E-111 Alumina L, Density = 3.887, Distilled Water, Marasperse N, AA Glass-fiber, Filter Media.

E-111 Alumina L - Original Dust				E-111 Alumina L Recovered from Pads			
Test No. 77		Test No. 79		Test No. 84 = 79.7%		Test No. 85 = 77.7%	
Size Microns	Percent Larger	Size Microns	Percent Larger	Size Microns	Percent Larger	Size Microns	Percent Larger
Sieve Analysis							
250	.00001	250	.00001				
105	.0007	105	.0007	105	.0005	105	.0011
74	.0045	74	.0045	74	.0040	74	.0041
44	.0266	44	.0267	44	.0303	44	.0208
Sedimentation Analysis							
32.8	.0389	32.9	.0411	32.8	.0250	32.5	.0210
23.0	.0724	23.0	.0865	23.0	.0708	22.8	.0343
18.6	.0886	—	—	—	—	—	—
15.9	.0897	16.1	.116	16.1	.0840	16.0	.0693
11.1	.185	11.02	.206	11.22	.154	11.17	.152
6.94	.384	7.02	.394	7.03	.360	6.98	.378
4.85	.601	4.90	.601	4.90	.570	4.89	.600
3.39	.781	3.41	.784	3.42	.750	3.42	.778
2.38	.886	2.36	.890	2.39	.860	2.38	.873
1.83	.924	1.91	.921	1.84	.907	1.88	.914
1.01	.963	1.03	.966	1.022	.956	1.03	.957

suspension medium would have been advantageous in covering the larger sizes; however, the distortions shown are well within the usual limits of accuracy expected with the Andreasen method.

The combined sieve and sedimentation procedure previously described for making particle size analysis and used in conjunction with the sampling equipment has been found useful for most of the various dusts encountered by the dust control industry. The combined procedures were preferred mainly because both methods have proved accurate, data were easily reproduced when proper precautions were taken, the methods gave direct results in percent-by weight, which were of primary concern, and, these methods proved most convenient and applicable to wet samples, which was especially important since the best dust recovery from the sampling pad was by the spray-washing process.

Other methods for determination of particle sizes in the sub-sieve range were used occasionally when the dusts were not suitable for wet recovery, or, when the particle size range was less than one micron. On these occasions either light [13,14] or electron microscopes[15] proved useful. Ordinarily, however, use of these instruments introduced problems which were better avoided than solved from the standpoint of expediency especially since the measurements, to be useful, had to be converted to a weight basis. Where there was a wide size-distribution in the dust sample to be analyzed, it was necessary, when using a microscope, to tediously count a prohibitively large number of particles in order to compensate for the inclusion or omission of just one large particle, and even then doubt as to whether a representative sample of the whole had been counted presented some cause for questioning the accuracy of the results. When the dust particles were irregularly shaped, a correct definition of the size presented an enigma. This is evident by the number of other investigators who have reported their work on this problem[16]. Good dispersion[17,18,19] of the particles on the microscope slide was absolutely essential, however it was often quite difficult, making definition of separate particles an arduous, if not impossible, task.

Other apparatus based on Stokes' Law for measuring particle sizes, which were known to produce accurate results, and which were considered for use in conjunction with the samplers were the hydrometer, turbidimeter, and air elutriator.

The hydrometer method[20,21,22,23] makes use of the change in specific gravity of a suspension as the index of concentration of material remaining in suspension. The method[24] was found to be as accurate as the Andreasen pipette method when proper precautions were taken, and was found to be quite convenient; however, the fact that at least 50 grams of dust were required for analysis excluded this method from serious consideration.

The Wagner Turbidimeter,[25,26,27] one of the most rapid particle size analysis methods, which utilizes photometric principles as the index of concentration of the suspended dust, requires only 0.5 grams of dust for analysis, and appears to be quite accurate for certain types of dust. Its accuracy suffers, however, when pigmented dust, dusts of various colors and degrees of opacity are to be measured.[28,29]

The air elutriator method[30,31,32] is essentially a sedimentation process in which a metered volume of air is aspirated over the dust, carrying upward those dust particles too small to settle against the upward velocity of the air. The dust is classified in a series of cone-shaped receptacles of varying diameters. Elutriation methods yield fractionated products which may be studied separately from the whole material. Once again, however, the size of the sample required for accurate analysis, approximately ten times the density[33] of the material (usually more than 20 grams), made this method incompatible with any convenient dust sampling procedure.

Typical Dust Sampling and Analysis Problem

IN THE FOLLOWING typical example, knowledge of the dust content in a given stack effluent, and the particle size of this dust were required so that a recommendation could be made as to what type of dust collector would be best suited for cleaning the effluent gas. This gas, for practical calculations was dry air at 600°F., and at atmospheric pressure.

The first step in the procedure was the measurement of the total gas flow, which

was accomplished by a Pitot tube traverse of the effluent stack. The thirty-six point traverse of the rectangular stack showed a total steady flow of 24,300 cfm @ 600°F.

At one of the points chosen for sampling, the Pitot tube reading was .24 inches W.G., giving a duct velocity of 2780 fpm.

$$\left\{\text{Vel. (ft./min.)} = 1096.5 \left[\frac{\text{Pitot tube differential (In.W.G.)}}{\text{Gas density (lb./ft.}^3\text{)}}\right]^{1/2}\right.$$

$$\left. = 1096.5 \left[\frac{0.24}{\frac{0.75 \times 530}{1060}}\right]^{1/2} = 2780 \text{ ft./min.} \right\}$$

The sampling tube chosen in this case was 1½ inch I.D. and the flow rate through the orifice in the sampler was adjusted to maintain this velocity, 2780 ft./min. through the tube. The flow rate, incidently, was 34 cfm @ 600° F. at the sampler inlet, and, 27.5 cfm at the orifice within the sampler where the temperature had fallen to 400° F. (For continuous flow within a given duct with dry air, $Q_1/T_1 = Q_2/T_2$, where Q and T are volume flow and absolute temperature respectively.)

A total sample of 39.822 grams was collected at this point during a ten minute sampling period, representing a grain loading for the stack effluent of 1.806 grains per cubic foot at 600° F. The total discharge from the stack at this grain loading was then:

$$\frac{1.806}{7000} \times 24{,}300 \times 60 = 376 \text{ pounds per hour,}$$

or 9030 pounds per 24 hour day. Since the amount of dust sampled, 39.822 grams, was more than ample for accurate analysis, a small representative section of the filter containing about one-fifth of the sample was used for analysis. The chosen section was washed according to the previously described procedure, using distilled water.

After removal of the glass fibers, a sieve analysis was made of the portion of the dust greater than 44 microns in diameter (Fig. 6). All of the dust was then recombined and the excess wash water was eliminated by sedimenting in a shallow container and siphoning off the clear supernatent liquid.

The dispersing agent, Marasperse N, was added to the remaining slurry in a concentration approximating 2% of the dry dust

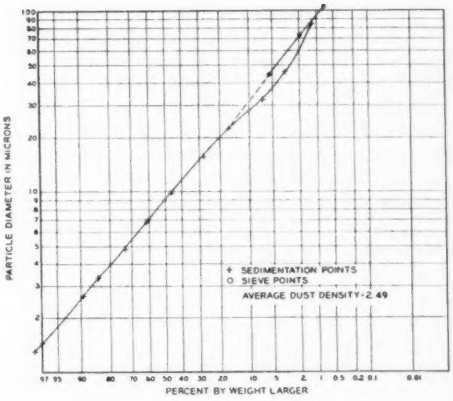


Fig. 6.
Particle size analysis of fly ash from typical dust problem.

weight. The slurry was then mixed for two minutes in an electric blender and poured directly into the sedimentation pipette adjusted to the correct volume and temperature required in the sedimentation procedure, and again, thoroughly remixed. The slurry was maintained at a constant 76°F. throughout the analysis.

Pipette samples were drawn at time intervals representing approximately a geometric progression. Each sample was dried and weighed. After the last sample had been drawn, the remaining pipette content was evaporated to dryness and the total weight of the solids in the suspension was accurately determined from this weight plus the total weight of the samples drawn, with the necessary corrections made for the small percentage of soluble materials and for the weight of the dispersing agent which had been added.

The results of the sedimentation analysis are shown, with the previously mentioned sieve analysis, in Fig. 6. Discrepancies in the overlapping range of the sieve and sedimentation analysis have sometimes appeared with non-homogeneous dust samples. The discrepancy here was probably due to the differences in density of the dust in the various size ranges. In these tests an average density of 2.49 grams per cubic centimeter was determined for the entire dust sample and was used to calculate the equivalent Stokes' spherical particle size. How-

ever, a density of only 1.923 grams per cubic centimeter was determined for the dust fraction greater than 44 microns. It would have been prohibitively difficult, if not impossible, to evaluate the size limits of these various fractions of different densities. Particle size calculations for this dust, using the lower density for the largest 20% fraction of the dust brought the sedimentation curve into better agreement with the sieve curve; however, because of incomplete knowledge of the changes in density for the various size ranges, the curve shown in Fig. 6 was calculated according to the average density only, as stated previously.

Conclusions

IN REVIEWING the methods used in sampling and in the analysis of the collected dust, it is apparent that for most practical purposes the results obtained are reliably accurate. It is apparent too, however, that in some portions of the procedures, particularly in the size-analysis, that problems occasionally arise where the methods revert to being an art and not a mere mechanical procedure, and that then the skill and patience of the analyst play a large part in the final accuracy of the results.

Bibliography

1. WATSON, H. H.: Errors Due to Anisokinetic Sampling of Aerosols. *Amer. Indust. Hyg. Assn. Quarterly*, 15:1, March, 1954.
2. SCHWEYER, H. E., and WORK, LINCOLN T.: Methods for Determining Particle Size Distribution. Amer. Soc. Testing Materials, Symposium on Particle Size, 1941.
3. WORK, LINCOLN T.: Methods of Particle Size Determination. *Proc. Amer. Soc. Testing Materials*, 28:771-811, 1928.
4. LAMAR, R. S.: A Review of Methods for Determining Particle Size Distribution of Ceramic Raw Materials. *Ceramic Bulletin*, 31:8, pp. 283-288, 1952.
5. DALLA VALLE, J. M.: The Technology of Small Particle Micromeritics. Pitman Publishing Company, New York, 1953.
6. HERDAN, G. and SMITH, M. L.: Small Particle Statistics, Elsevier Publishing Company, Houston.
7. ROSE, H. E.: The Measurement of Particle Size in Very Fine Powders. Constable and Company, Ltd., Toronto, Canada, 1953.
8. ANDREASEN, A. H. M.: Uber Die Gultigkeit Des Stokes' Schen Gesetzes Fur Nicht Kugelformige Teilschen. Kolloid Zeitschrift, 48:175, 1929.
9. ANDREASEN, A. H. M., and LUNDBERG, J. J. V.: Apparat Zur Betriebsmassigen Feinheitz—Bestimmung Der Mortelstaffe Und Uber Einige Damit Ansgefuhert Untersuchunger. Zement, 19:698, 1930.
10. Standard Method of Mechanical Analysis of Soils. *Amer. Soc. Testing Materials*, D-422-51, pp. 211-221.
11. Tentative Method of Test for Kinematic Viscosity. *Amer. Soc. Testing Materials*, D 445-46T.
12. Standard Methods of Test for Specific Gravity of Pigments. *Amer. Soc. Testing Materials*, D 153-39.
13. PERROTT, G. ST. J., and KINNEY, S. P.: The Meaning and Microscopic Measurement of Average Particle Size. *J. Amer. Ceramic Society*, 6:417, 1923.
14. See (3).
15. WYCKOFF, RALPH W. G.: Electron Microscopy, Interscience Publishers, Inc., New York, 1949.
16. SCHWEYER, H. E.: Particle Size Studies, Properties of Finely Divided Materials. *Chemical Reviews*, 31:295-317, October, 1942.
17. GREEN, HENRY: A Photographic Method for the Determination of Particle Size of Paint and Rubber Pigments. J. Franklin Inst., 192:637 1921.
18. ALLEN, R. P.: Preparation of Pigment Mounts for Microscopy. *Industrial and Engineering Chemistry, Anal. Ed.*, 14:1, January, 1942.
19. See (15).
20. BIDDLE, S. B., JR. and KLEIN, ALEXANDER: A Hydrometer Method for Determining the Fineness of Portland-Puzzolan Cements. *Proc. Amer. Soc. Testing Materials*, 36:2, 310, 1936.
21. THOREEN, R. C.: Comments on the Hydrometer Method of Mechanical Analysis. *Public Roads*, August, 1933, pp. 93-105.
22. See (10).
23. BOUYOUCOS, GEORGE JOHN: A Sensitive Hydrometer for Determining Small Amounts of Clay or Colloids in Soils. *Bulletin Amer. Ceramic Society*, 17:254, 1938.
24. SCHWEYER, H. E.: Particle Size Studies—Methods. *Industrial and Engineering Chemistry, Anal. Ed.*, August, 1942, pp. 622-632.
25. WAGNER, L. A.: A Rapid Method for the Determination of the Specific Surface of Portland Cement, *Proc. Amer. Soc. Testing Materials*, 33:2, 553, 1933.
26. Report on Cooperative Sub-Sieve Fineness Tests by the Working Committee On Fineness. *Amer. Soc. Testing Materials.*
27. Standard Method of Test for Fineness of Portland Cement by the Turbidimeter. *Amer. Soc. Testing Materials*, D-445-46T.
28. See (24).
29. SCHWEYER, H. E.: Measurement of Particle Size Distribution by Optical Methods. *Industrial and Engineering Chemistry*, 9:5, 211-212, May 15, 1937.
30. ROLLER, PAUL S.: Size Distribution of Ceramic Powders as Determined by A Particle Size Analyzer. Abstract presented at the Annual Meeting, American Ceramic Society, Columbus, O., March 31, 1936. *J. Amer. Ceramic Society*, 20:67, 1937.
31. ROLLER, PAUL S. and ROUNDY, P. V., JR.: Surface Area of Portland Cement. *Amer. Soc. Testing Materials*, Symposium on Particle Size, 1941.
32. ROLLER P. S.: Measurement of Particle Size With an Accurate Air Analyzer: The Fineness and Particle Size Distribution of Portland Cement. *Proc. Amer. Soc. Testing Materials*, 32:2, 667, 1932.
33. POLLARD, ROLLA E.: Subsieve Particle-Size Measurement of Metal Powders by Air Elutriation. *Journ. of Research of the Nat. Bur. of Standards*, 51:1, July, 1953, Research Paper 2428.

Additional Bibliography

SCHWEYER, H. E.: Particle Size Distribution. Rock Products, No. 1942, pp. 56, 94-96.

HEISS, JOHN F., and COULL, JAMES: On The Settling Velocity of Non-Isometric Particles in a Viscous Medium. *Chemical Engineering Progress*, 48:3, 133-140, 1952.

HINKLEY, W. O.: Determination of Particle Size Distribution. *Indust. and Engineering Chem., Anal. Ed.*, 14:1, 10-13, January 15, 1942.

ANDREASEN, A. H. M.; BERG, SOREN; and KJAER, E.: Several Colloid-Grinding Investigations with a Ball Mill. Kolloid A., 82:37, 1938.

HEYWOOD, HAROLD: Calculation of the Specific Surface of a Powder. *Inst. of Mech. Engineers' Proceedings*, 125: 383-459, 1933.

PETERSEN, E. E.; WALKER, P. L.; and WRIGHT, C. C.: Mathematical Analysis of Size-Frequency Distribution of Particles in the Subsieve Range. Amer. Soc. Testing Materials Bulletin, No. 183, July, 1952, pp. 70-75.

ALLEN, R. P.: Technical Microscopy in the Rubber Industry. *Indust. and Engineering Chem., Anal. Ed.*, 14:9, 740-750, September, 1942.

GAMBLE, D. L., and BARNETT, C. E.: Scattering In The Near Infrared, A Measure Of Particle Size And Size Distribution, *Indust. and Engineering Chem., Anal. Ed.*, 9:7, 310-314, July 15, 1937.

ADLER, C. R.: MARK, A. M.; MARSHALL, W. R., JR.; and PARENT, R. J.: A Scanning Device for Determining the Size Distribution of Spray Droplet Images. *Chem. Engineering Progress*, 50:1, 14-23, January, 1954.

CARTWRIGHT, J., and SKIDMORE, J. W.: The Measurement of Size and Concentration of Airborne Dusts with Electron Microscope. Safety in Mines Research Establishment, Research Report No. 79.

FRANKLIN, A. D.; CAMPBELL, R.; and WEINMAN, J.: Measurement of Particle Size of Fine Ferromagnetic Powders. *J. Applied Phys.*, 24:8, 1040-1045, August, 1953.

WEST, W. J.: Size Determination of Clay Particles in Water Suspensions by Use of Low-Angle X-Ray Diffraction. *J. Colloid Sci.*, 7:3, 295-305.

SMITH, DANIEL and GREEN, HENRY: Measuring The Specific Surface Of Particulate Substances, *Indust. and Engineering Chem., Anal. Ed.*, 14:5, 382-386, May 15, 1942.

SCHWEYER, H. E.: Particle Size Studies—Effects of Viscosity of Medium on Rate of Grinding in Pebble Mills. *Indust. and Engineering Chem.*, 34:9, 1060-1065, September, 1942.

SILVERMAN, LESLIE: Industrial Air Sampling And Analysis. Chemistry and Toxicology Series, Bulletin No. 1, 1947.

BERG, SOREN: Studies on Particle Size Distribution. G. E. C. Gad. Kommission Hos, Kobehaven, Danmark, Tlf, Byen 3580 Oster Voldgade 60, KBH, K, August, 1940.

HAUSER, E. A., and REED, C. E.: Studies In Thixotrophy: I. Development of a New Method for Measuring Particle-Size Distribution In Colloidal Systems. *J. Phys. Chem.*, 40:1169-82 1936.

Renewal Reminder

A LARGE percentage of the subscriptions to the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION QUARTERLY are on a calendar year basis. These subscriptions expire with December issue. Renewal notices will be sent to non-members in January. In order to assure prompt delivery of the Quarterly for 1956, readers are asked to return the renewal notices at an early date.

Available Reprints

THE INDUSTRIAL Hygiene Foundation, Mellon Institute, announces that the following reprints are available for free distribution: "Biologic Testing of New Materials of Fine Particle Size" by Paul Gross, M.D.; "Toxicological Study of Calcium Halophosphate Phosphors and Antimony Trioxide" by Paul Gross, M.D. et al. The reprints may be obtained by addressing your request to the Industrial Hygiene Foundation, Mellon Institute, 4400 Fifth Avenue, Pittsburgh 13, Pa.

ATTENTION
INDUSTRIAL HYGIENISTS

Dithizone Method of Lead Determinations in Blood or Urine Our Specialty

Bacteriology — Trace Elements
Toxicology — Industrial Hygiene

Consultation and Chemical Research

CENTRAL LABORATORIES
312 David Whitney Building
Telephone: Woodward 3-1030 Detroit 26, Mich.

CHapman 5-6563 CItrus 4-3727

ALBERT L. CHANEY
CHEMICAL LABORATORY
1503 East Chevy Chase Drive
Glendale 6, California

CONSULTATION and RESEARCH

AIR POLLUTION
INDUSTRIAL HYGIENE
AND
TOXICOLOGY

TRACE ELEMENT
AND
MICROCHEMICAL
ANALYSES

Particulate Atmospheric Carbon

A METHOD FOR THE DETERMINATION OF SOURCES

GEORGE D. CLAYTON, Consulting Engineer, Detroit
JAMES R. ARNOLD, Institute for Nuclear Studies, The University of Chicago
FRANK A. PATTY, Industrial Hygiene Department
Research Laboratories Division, General Motors Corporation, Detroit

THE LOS ANGELES "smog" is probably the most publicized of any air pollution problem. Millions of dollars have been spent, and additional millions are presently being expended in an effort to determine the causative agent or agents producing the eye irritation, reduced visibility, rubber cracking, and plant damage. The attack on the problem by the multitude of agencies and organizations may be classified into two broad categories, that is, (1) determining the contaminant or contaminants causing the smog, and (2) determining the sources of pollution.

There is substantial evidence that an irradiated gaseous mixture of hydrocarbons and oxides of nitrogen produce the strong oxidizing property found in the Los Angeles basin air. It has been proven in experiments that a laboratory mixture having similar oxidizing properties to that found in the Los Angeles air (reported as ozone, with concentrations found as high as 1.0 ppm) can cause rubber cracking, eye irritation, and plant damage.

The sources of contaminants have been extensively studied, and it is reported that the largest quantity of air contaminants in Los Angeles originate from combustion processes. It is estimated that approximately half of the pollution is created by auto exhausts and backyard incineration. Based on the consumption of gasoline, approximately 1,000 tons of hydrocarbons, 300 tons of organic acids and aldehydes, oxides of nitrogen and sulphur are emitted from the exhaust pipes daily.

Larson[1] states that on the basis of three pounds of rubbish per person per day, commercial and household rubbish amounts to about 6,000 tons daily, with most of this material being disposed of by backyard incineration. Industrial rubbish, amounting to 3,000 tons per day, is handled either by industrial incineration or by "cut and fill" operation.

Athough extensive work has been done in studying the effluent of single pollution sources, it has been understandably difficult to relate these findings to what is found in the general atmosphere.

It is well known that particulate matter in the atmosphere influences visibility. Photographs taken while backyard incineration was in progress show the effect this source has in reducing visibility in Los Angeles. It was the purpose of the investigators to study the origin of the carbon constituent of atmospheric particulate matter.

There exists an unequivocal method of distinguishing between carbonaceous material arising from biological sources and that from fossil fuels such as coal, oil, and natural gas. This method is based on the carbon 14 content of the living materials.[2] It has been shown that all biological materials contain an almost exactly constant proportion of radioactive carbon 14 to normal carbon. The half-life of carbon 14 (about 5,600 years) insures that no activity remains in the carbon of fossil fuels. Materials of ages from 1,000 to perhaps 40,000 years contain intermediate but detectable amounts of carbon 14 activity. Since the materials contaminating the atmosphere above a city are either contemporary (that is, containing the same amount of activity as all other living materials) or inert, a measurement of the carbon 14 activity of such a sample will indicate the fraction due to biological sources of all kinds. These might include carbon from trash burning, pollen, forest fires, etc.

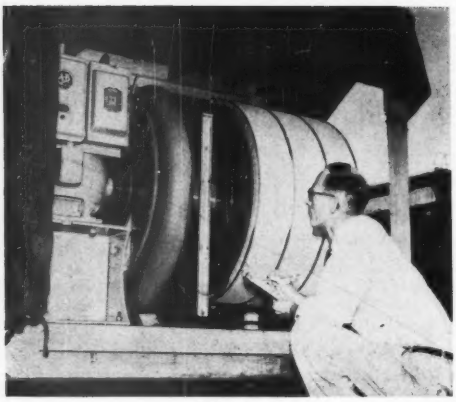


Fig. 1.

Instrument

TO DETERMINE the carbon content of the particulate matter in Los Angeles atmosphere during a period of smog, a special sampler was constructed, described as follows (Fig. 1):

The fan was American Blower Size 6 Type F 28" wheel driven by a 25 hp 220 volt motor.

The filter cage or holder is 38" in diameter with a screened surface 2 feet wide and 10 feet in circumference. An inner screen was made of ½" mesh hardware cloth covered with 16 mesh bronze screen. This filter cage was equipped with four quick acting bands to hold three strips of 8" filter in position over the screen. The outlet side of the fan was equipped with a 3⅜" orifice plate so as to hold the amperage of the motor down to within the permissible load. The inlet side of the fan, between fan and filter, was equipped with a 5" diameter plate orifice and manometer for estimating air flow rates. One water manometer indicates the pressure across the orifice plate while another indicates the total suction on the filter.

The sampler was calibrated by means of a pitot tube and found to sample at an average rate of about 1000 cubic feet per minute.

The collecting media was Hurlbut fiber No. 935 with a distortion point of 611°C; 99.95% efficient in 0.3 microns DOP smoke particles; resistance, 110 mm water at 28 feet per minute. AAA glass fibers 0.5-0.75 micron in diameter. The material used was purchased from the Mine Safety Appliance Company.

Measurement Procedures

THE C^{14} assay of these samples was measured by a liquid scintillation method.[3] This involved the conversion of the sample carbon into liquid hydrocarbon suitable for measurement. The procedure is briefly as follows: the sample is burned in a stream of oxygen, and the resulting carbon dioxide collected in ammonium hydroxide solution. It is then precipitated as strontium carbonate, which is converted to the carbide by reaction with magnesium metal. This is then hydrolyzed to give acetylene, which is polymerized in the presence of cuprous chloride to give unsaturated C_6 and C_8 hydrocarbons. These are then hydrogenated to give a product which is chiefly hexane and octane. This chemical procedure was adapted, with modifications, from the work of Suess[4] and Nieuwland.[5] The carbon content of the liquid is determined by a combustion analysis, and the C^{13}/C^{12} ratio determined in order to correct for hydrocarbon fractionation in nature or in the laboratory.

The method of measuring the carbon 14 content of the sample has been previously described.[3] A number of minor improvements will be described in a later publication. Because of the small size of the samples involved, a cell of 10 cc capacity was used. With a sample of approximately two grams of liquid hydrocarbon, we were able to measure the percentage of living carbon to 1.5% in 24 hours of counting.

Sampling Period and Locations

SAMPLES were collected at one location in Detroit and one location in Los Angeles. It may be noted that the sampler operated from four to six days for each sample. The selection of sampling sites and the collection of samples were under the supervision of Vincent J. Castrop, Industrial Hygiene Department, General Motors Corporation.

Detroit Sample No. 1: September 3, 1954 at 2:25 P.M. continuous to September 7, 1954 at 8:15 A.M. Location: roof of 11-story General Motors Research Building.

Detroit Sample No. 2: September 7, 1954 at 9:35 A.M. to 2:20 P.M.; September 13, 1954, intermittently while calibrating for

approximately two hours; September 14, 1954 at 8:45 A.M. continuous to September 16, 1954 at 8:45 A.M. Same location as Detroit Sample No. 1.

Los Angeles Sample No. 1: October 14, 1954, one-half hour; October 15, 1954 at 8:30 A.M. continuous to October 19, 1954 at 4:20 P.M. Location: Brookside Park (about one-half mile south of Rose Bowl).

Los Angeles Sample No. 2: October 19, 1954 at 11:50 P.M. continuous to October 25 at 1:30 P.M. Location and filter area same as Los Angeles Sample No. 1.

Weather Conditions

IN DETROIT, haze, smoke and fog were moderately light and present less than 20% of the sampling period. There were winds of 5-15 miles per hour and brief showers. Visibility ranged from 3 to 14 miles and for most of the period was above 10 miles.

In Los Angeles both samples were taken during a period of fog and severe haze. Complaints of eye smarting were frequent during daylight hours.

Results of Study

TABLE I presents the results of the investigation. It is of interest to note that the total carbon content of each sample was only about 20% of the total weight. Thus carbon is a minor constituent in the total particulate load in the Los Angeles and Detroit atmosphere.

Beryllium 7 with a half-life of 53 days has recently been found to be produced by cosmic rays.[6] We have analyzed the present samples for beryllium 7 content. There is as yet an insufficient number of comparison samples to make the results highly meaningful. They are, however, presented in Table II. It is possible that when sufficient results are obtained, a useful measure of the rate of subsidence of the atmosphere in the Los Angeles area can be obtained using this isotope.

The sensitive counting techniques used in this study may be applied to tracer experiments as well as to natural activities. Simple calculation shows that it would be practical to introduce sufficient tracer, either carbon 14 or some other isotope, into any suspected source of contamination in an area the size of the Los Angeles basin, in order to determine the percentage of contamination arising from this particular source. For example, the entire gasoline supply could be "tagged" at an adequate level for a period of 30 days, in order to determine the contribution of automobile exhausts to atmospheric carbon. Since the level of radioactivity in the consumer product can be well below that of the human body, no hazard to the public is involved.

TABLE I.
CARBON ANALYSIS OF AIR SAMPLES

Sample	Air Vol. mcf*	Total Wt.†	Total Carbon†	% Contemporary Carbon
Detroit #1	6.1	35	6	***
Detroit #2	3.2	18**	3**	12.6 ± 3.0
Los Angeles #1	6.25	31	6	25.7 ± 1.6
Los Angeles #2	8.5	41.7	8	23.2 ± 1.4

* Million cubic feet. ** Approximate - filter torn.
*** Sample lost in processing. † Weight in grams.

TABLE II.
BERYLLIUM 7 ANALYSIS OF AIR SAMPLES

Sample	A° *
Detroit #1	4.5
Detroit #2	1.0
Los Angeles #1	1.3
Los Angeles #2	2.4

* Units are distintegrations per minute Be^7 per 10^3 cubic feet at the time of collection.

Conclusions

THE TESTS conducted proved the effectiveness of the technique used, and reveal that this procedure is a useful tool in determining whether or not the atmospheric particulate carbon is newly formed, as from rubbish burning, or is aged, as from petroleum, coal and gas sources.

References

1. LARSON, G. P.: Problems of Rubbish Disposal as Affecting Air Pollution, Los Angeles. Conference on Incineration, Rubbish and Air Pollution, Air Pollution Foundation, Report No. 3, Los Angeles, California, January, 1955.
2. LIBBY, W. F.: Radiocarbon Dating. University of Chicago Press, Second Edition, 1955.
3. ARNOLD, J. R.: *Science*, 119:155, 1954.
4. SUESS, H.: *Science*, 120:5, 1954.
5. NIEUWLAND, J. A.; VOGT, R. R.: The Chemistry of Acetylene. Reinhold Publishing Corporation, New York, 1954.
6. ARNOLD, J. R.: *Science*, 121:451, 1955.

Lead in Blood

A RAPID METHOD FOR SPECTROCHEMICAL ANALYSIS

KATHLEEN KUMLER and THOMAS P. SCHREIBER
Research Laboratories Division
General Motors Corporation, Detroit

EACH YEAR in this laboratory approximately 8,000 blood specimens are analyzed for lead. Because of this, there has been an interest in an accurate but more rapid method than wet ashing with subsequent determination of lead as the dithizonate.

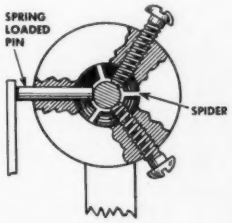
Spectrographic determination of lead in biological materials has been described by Cholak et. al.[1,2,3,4] Following a similar procedure, good correlation was obtained between chemical and spectrographic results on specimens divided quantitatively after oxidation. However, this spectrographic method offered no advantage in rapidity of analysis. The blood still had to be completely oxidized; and reading spectrographic plates for both lead and bismuth lines (bismuth being the internal standard) together with the spectral background adjacent to these lines was tedious and time-consuming.

In the method to be described, 30 to 40 bloods can be analyzed by one person in a day. If necessary one or two can be completed in less than 45 minutes. This has been accomplished, first, by cutting the time of preparing the sample for the arc approximately 50%; second, by reducing the spectral background to the point where its measurement is unnecessary. This reduction has been attained by the use of a narrow slit and nitrogen in the analytical gap. Freedom from contamination, necessary for accuracy, is largely due to the electrode loading technique.

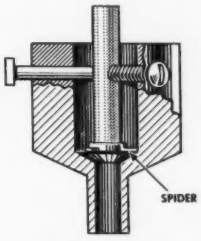
Equipment and Reagents

THE FOLLOWING equipment and reagents are necessary for the procedure to be described:

1. 800 ml. Vycor Kjeldahl flasks.
2. Conc. nitric and sulfuric acids, lead-free.
3. Lead-free water.
4. Bismuth-sodium chloride solution.
   a. Soln. I-20 mg Bi/ml: Dissolve 2.0 g. spectroscopically pure metallic bismuth in 20 ml conc. HNO_3; dilute to 100 ml with water.
   b. Soln. II-1 mg Bi/ml: 10 ml conc. HNO_3 added to 10 ml I and diluted to 200 ml.
   c Bismuth-salt soln: Dissolve 200 g. NaCl in approximately 800 ml water in 1 liter volumetric flask. Add 40 ml II (40 mg Bi) and dilute the combined Bi and NaCl solutions to one liter.
5. Standard solutions are prepared as follows: Varying amounts of a standard $Pb(NO_3)_2$ solution (0.001 mg Pb/ml), 50 ml conc. HNO_3, and 50 mg Fe (10 ml of $FeCl_3 \cdot 6\ H_2O$ aqueous solution) are diluted to 100 ml and 25 ml of bismuth-salt solution added. Only the lead and salt solution measurements require accuracy since the lead-to-bismuth ratio is critical.
6. All glassware is cleaned in hot 15% HNO_3 and thoroughly rinsed with lead-free water.
7. Spectrographic apparatus and materials.
   a. Bausch and Lomb large Littrow; region #5.
   b. Optical conditions; spectrograph slit width, 10 microns: An image of the electrodes is focussed on objective lens by means of a 10 cm focal length lens positioned ten cm from the slit. These optical conditions utilize the full speed of the instrument. Setting the entrance slit at 10 micron instead of the customary 20 micron aids in reducing the spectral background.



TOP VIEW



SIDE VIEW

Fig. 1.
Electrode holder.

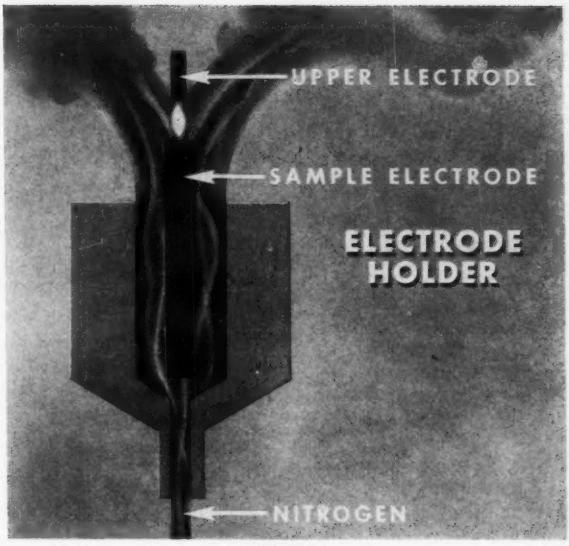


Fig. 2.
Electrode holder.

It is important that the instrument be in accurate focus to prevent interference from an iron line close to the lead line.

c. Source: Direct current arc, 230 volts, 10 amperes.

d. Photograhic: Eastman Kodak Spectrum Analysis #1 plates developed five minutes in D-19 and fixed two minutes in Kodak acid fixer. (Applied Research Laboratories developing machine) The following four iron lines are used for emulsion calibration:

	ratio
2813.289 A	5.8
2823.28 A	1.6
2832.43 A	3.5
2838.12 A	1.0

e. Microphotometer — National Spectrographic Spec Recorder; slit width at plate, 12 microns.

f. Sample electrode holder construction is shown in Fig. 1. The electrode is held in place by two screws and a pin at the top, and a spider at the bottom. This holder is so designed that gas can be introduced into the analytical gap by blowing it up along the sample electrode. The holder consists of a metal cup with a hole in the bottom, through which nitrogen is introduced at a rate of three to four liters per minute (Fig. 2).

The use of nitrogen has improved the arc performance in two important respects: first, it stabilizes the arc by preventing its wandering down the side of the electrode; second, it improves the intensity of the analytical lines with respect to the spectral background.

g. Electrodes: National Carbon "SP" grade graphite; ¼ inch lower, ⅛ inch upper.

h. Nitrogen: Airco dry nitrogen; flow rate regulated by Airco Flow Meter, style 8467, maximum flow rate 15 liters per minute; regulator 3000#.

Procedure.

THE BLOOD specimen, usually around 20.0 g., is transferred to an 800 ml Vycor Kjeldhal flask containing 5 ml bismuth-salt solution. Bismuth is the internal standard; salt acts as an arc stabilizer. Should the blood be less than 10.0 g., 2 ml of solution, instead of 5 ml, are added to maintain more uniform concentrations. One ml conc.

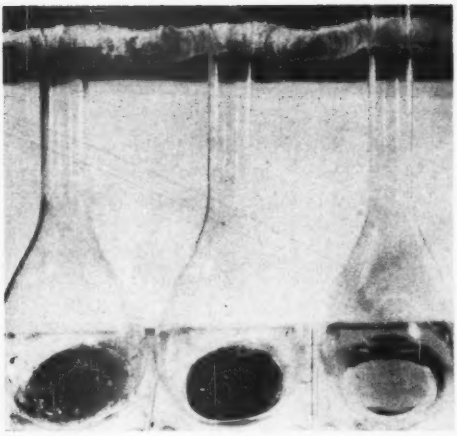


Fig. 3.

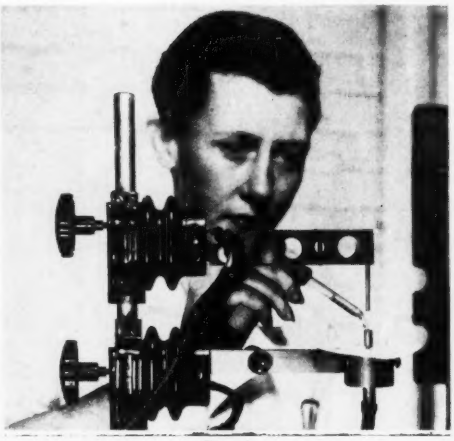


Fig. 4.

H_2SO_4 and 20 ml conc. HNO_3 are added to the flask and heat is applied for 10 to 15 minutes. The cold mixture has a dark clotted appearance as shown in the flask on the left in Fig. 3. After a few minutes heating, the large clots are broken up into smaller fragments and the solution is still dark as in the center flask. Continuing the heating results in an apparently homogeneous, amber-colored solution, on the right. This takes about 15 minutes. The solutions do not all have exactly the same appearance; some may look clear; some, turbid. Insolubles may form on cooling but heat returns them to solution.

The electrodes are preburned at 10 amperes for 10 seconds with the spectrograph shutter closed. After a cooling period of about 15 seconds, but while the electrode is still quite warm, a drop of sample is applied (Fig. 4). The paper apron is used to prevent the sample from entering the holder. As the heat of the electrode holder increases with use, the cooling of the electrode takes longer. If the electrode is too hot, the sample will sputter off; if too cool, it will not dry. Experience with application is the best guide. Under proper conditions, the sample dries in a few seconds (Fig. 5). "Dry" may not be the best descriptive term, it really looks gelatinous. When gaseous bubbles cease to be evolved, it can be arced. A hair-drier has been found useful both in cooling the electrodes and drying the samples. This electrode loading technique has proved remarkably free from contamination due primarily to the purging effects of the preburn and the very short time the sample is exposed.

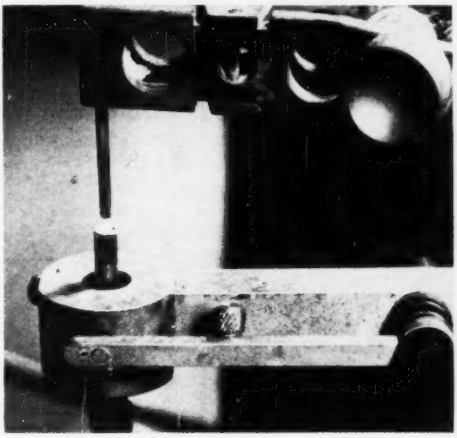


Fig. 5.

The spectrograph shutter is opened, the sample is arced 10 seconds and the electrodes cooled. Without racking the plate, a second drop is applied to the same electrode and arced. The resulting spectral lines are thus an integration of two 10-second exposures. For the quantities of lead found in blood there is not sufficient intensity with one exposure, nor does additional sample on the electrode increase that intensity. Better reproducibility is obtained with a minimum of sample.

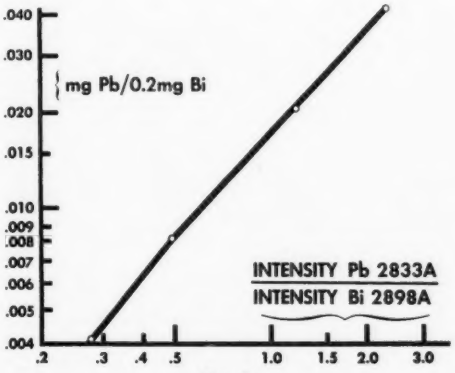


Fig. 6.
Analytical curve—average of synthetic standards.

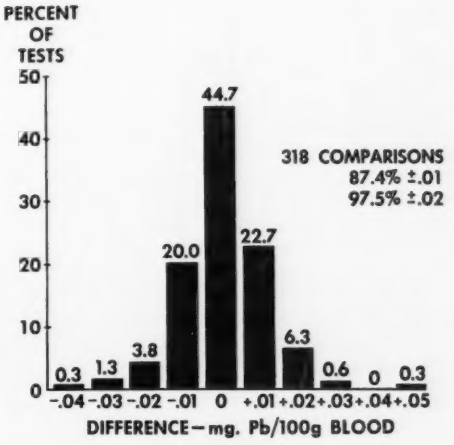


Fig. 7.
Comparison of chemical and spectrographic results.

This procedure is carried out twice for each sample, twice also for each of the four standards run on every plate. Convenient standards range from .004 to .040 mg Pb per 0.2 mg Bi, which is the amount of Bi in 5 ml of the salt solution.

For 20.0 g. samples, these represent values from .02 to .20 mg Pb per 100 g. blood. Standard samples are run on each plate when there is difficulty in reproducing a slit width setting of 10 microns.

The lead 2833 and bismuth 2898 A lines are read on the microphotometer. The percent transmission readings thus obtained are reduced to the lead-to-bismuth intensity ratio by means of an emulsion calibration curve. This is obtained for each plate by using four iron lines which appear in the sample spectra and have known relative intensities.

The amount of lead in the sample is determined from an analytical curve obtained by plotting the intensity ratios of the standards versus their lead concentrations. Fig. 6 is a typical analytical curve representing the average ratios of lead standards from nine plates which were run when the slit width had remained constant. When the slit is not fixed at 10 microns, this curve shifts laterally but individual curves from each plate have the same slope.

Accuracy

ANY NEW spectrochemical method stands or falls on the chemical analyses behind it. To establish accuracy, over 300 bloods were analyzed both with this method and chemically. After the few drops were removed for spectrographic analysis, the remainder of the specimen was oxidized completely and lead determined colorimetrically following separation from bismuth at pH 3.4 according to Bambach and Burkey.[5] No correction was applied for the amount removed. The results of 318 such comparisons are shown in Fig. 7.

The spectrographic results are compared to the chemical findings, assuming the latter to be correct. Results are rounded off in both cases to the nearest hundredth of a milligram of lead per 100 g. blood: 142, or 44.7%, of the results show no difference; 64, or 20%, are -.01; 72, or 22.7%, are + .01. This means that 278, or 87.4%, are within ± .01; 97.5% are within ± .02. In this laboratory where six people are currently engaged in all phases of chemical blood lead analysis, it has been estimated that the reported lead levels are accurate to within ± .01. Since 97.5% of these comparative results are within ± .02, this spectrochemical method seems practical. The spectrographic results were obtained by five chemists whose only spectrographic training consisted of running a few plates of standards for reproducibility.

A number of these 318 results were obtained when the slit was judged to have remained at 10 microns. They were deter-

mined from the average standard curve (Fig. 6). No standards were run on the plates. The curve is again shown in Fig. 8. In addition, the lead found chemically in 61 blood specimens is plotted against the spectrographic intensity ratios for the same specimens. A definite pattern is evident; most of the points are close to or on the standard curve. These points represent the amount of lead found chemically in the specimen. In terms of the reported values, the symbols indicate the difference between spectrographic and chemical results. This gives an idea of the degree of accuracy that can be expected when using a standard curve; but this can be done only when the slit is constant.

Reproducibility

THE REPRODUCIBILITY of the method was checked by having samples analyzed on different plates by three different operators.

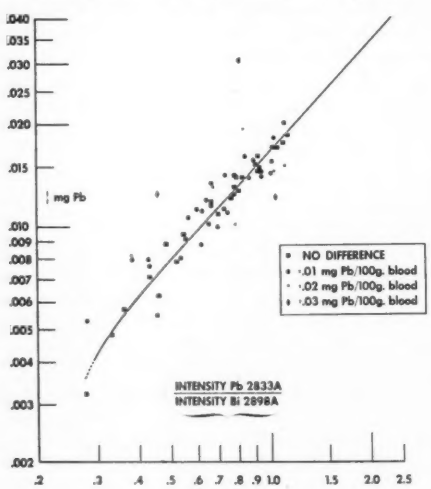


Fig. 8.
Comparison of chemical and spectrographic data—61 samples.

TABLE I.
REPRODUCIBILITY
mg. Pb/100g Blood

	Sample 1	Sample 2	Sample 3
Plate 1	.076	.048	.026
Plate 2	.066	.047	.031
Plate 3	.071	.052	.039
Plate 4	.055	.037	.026
Plate 5	.069	.042	.028
Average	.067	.045	.030
Reported	.07	.05	.03

Three typical sets of data are shown in Table I, representing results on three bloods from five plates. The average for each group of five results and the reported value also is given. If rounded off to the nearest .01 mg, 10 of the 15 results would be the same as the reported values; five would differ by ± .01.

Conclusion

THE SPEED of this method can be attributed to the following: The use of partially oxidized blood, the presence of nitrogen in the analytical gap, and a narrow (10 micron) entrance slit. In addition, possibility of contamination has been greatly reduced. This results from the electrode loading technique and the fact that very few reagents are added for analysis.

[The authors wish to acknowledge the assistance of Patricia Taylor, Jean Misenheimer, Marsha Gross and Robert C. Frank.]

Bibliography

1. CHOLAK, J.: Quantitative Spectrographic Determination of Lead in Biological Material. *Ind. Eng. Chem.* (Anal. Ed.), 7:287, 1935.

2. CHOLAK, J., and STORY, R. V.: Spectrographic Analysis of Biological Material. *Ind. Eng. Chem.* (Anal. Ed.), 10:619, 1938.

3. CHOLAK, J., and STORY, R. V.: Spectrochemical Determination of Trace Metals in Biological Material. *J. Optical Soc. Am.*, 31:730, 1941.

4. CHOLAK, J., and STORY, R. V.: Corrections for Residual Impurity and Background in Spectrochemical Analysis. *J. Optical Soc. Am.*, 32:502, 1942.

5. BAMBACH, K., and BURKEY, R. E.: Microdetermination of Lead by Dithizone. *Ind. Eng. Chem.* (Anal. Ed.), 14:904, 1942.

Position Open

THE CITY of Detroit is seeking an Associate Industrial Hygienist for supervision of industrial hygiene laboratory work. Post-graduate study in industrial hygiene or related fields and experience in supervision of industrial hygiene work are required. The beginning salary of $7,506.00 increases to a maximum of $8,349.00. Interested persons should contact the Detroit Civil Service Commission, City-County Building, Detroit 26, Michigan.

A Unique Wet Collector for Lightweight Aggregate Dusts

HARRY E. SEIFERT, Director, and JULIUS H. FANNEY, JR., Industrial Hygienist
Virginia Bureau of Industrial Hygiene, Richmond

LIGHTWEIGHT aggregate is a product of thermal expansion. Recently, the production of this material has created a new industry. In general, the process consists of first crushing weathered slate, shale, slack or similar materials; second, heating to approximately two thousand degrees Fahrenheit (2000°F) to expand and sinter; and finally recrushing and screening to the desired size. The final product is called "lightweight aggregate."

This product is being used in place of cinders in building block fabrication and stone in concrete construction. Not only does concrete made with lightweight aggregate have the same compressive strength as ordinary concrete, but it is approximately 40% lighter. Also, this material has good insulating qualities and does not exhibit iron spotting as normally experienced with cinders. Among the notable projects in which this material has been used were the rebuilding of the roof of the National Capitol in Washington, and the deck of the Chesapeake Bay Bridge at Annapolis, Maryland.

Presented at the Sixteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, April 28, 1955, Buffalo.

Fig. 1.
View of the six rotary kilns.

Fig. 2.
Discharge end of kilns showing operators' housing and piles of lightweight aggregate.

Fig. 3.
Partial view of plant showing rotary kilns, steel stacks, conveyors and discharge from dust collector.

At the plant discussed in this article, crushed weathered slate or shale was fed into one end of a horizontal round rotary kiln and pulverized coal was blown in at the other end. (Figs. 1 and 2) Since there were very few similar plants in operation when this plant was started, many of the procedures were worked out by trial and error. There also was some doubt in the beginning

as to the ability to produce a satisfactory product.

The plant was located in a rural area on the edge of a river valley, the river being across the flat about one mile. The nearest houses were approximately one mile from the plant and on higher ground.

The first kiln installed at this plant was equipped with a 48-foot stack. When the product from this kiln proved satisfactory, another unit was built immediately (Fig. 3). Shortly after the installation of the second kiln, complaints were received from residents who lived over a mile and a half away. Investigation proved that the complaints were justified. A visible reddish brown dust collected on the outside of the houses and also seeped into the houses around windows and door sills. The company then realized that they were creating a nuisance and immediately attempted to take corrective measures.

The first attempt to control the nuisance dust was the installation of a large low pressure cyclone. While this unit was being installed and tested, work on a third rotary kiln was started because of product demand. When this type of cyclone did not prove satisfactory in appreciably reducing the atmospheric dust discharge, a low pressure cyclone with a helical top was constructed and installed. In a very short time, this cyclone disintegrated because of the abrasive action of the dust. It was then realized that a collector of the *cyclone* type alone would not be satisfactory for this process.

Several of the large companies specializing in commercial dust collectors were then contacted and it was decided to try a wet type collector. This collector was purchased on a trial basis. However, before this collector could be installed, five rotary kilns were in operation. This new collector, which had the capacity for only four of the kilns, did an excellent job at first, allowing very little dust to escape to the atmosphere. However, after the wet collector had been in operation for six weeks, the metal had been weakened through abrasion and corrosion to the extent that it was possible to push holes in the side of the unit with one's fingers. After a series of conferences, the dust collector company agreed to line the inside of the collector with a special concrete to prevent erosion.

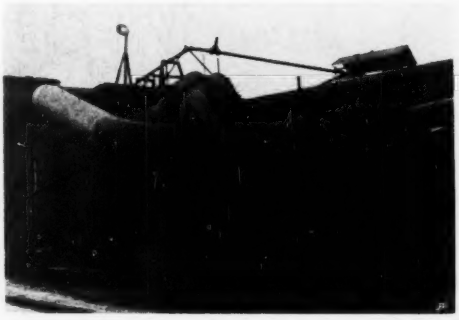


Fig. 4.
Inlet end of dust collector showing one of the fans.

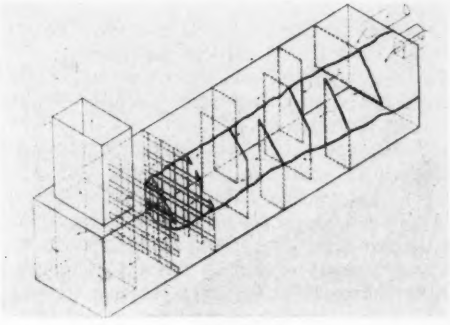


Fig. 5.
Schematic view of dust collector.

While the problem of the wet collector was being reviewed, a sixth rotary kiln was put into operation. This last kiln had twice the capacity of any of the other kilns and understandably increased the pollution problem proportionately.

During the summer when the wet collector failed the first time, the residents across the valley threatened to present a petition to the circuit court in an effort to halt production at the plant. When the situation was explained to the petitioners, a delay was obtained on final court action. After a period of several months, the dust collector firm lined the inside of the collector and it operated satisfactorily for another period of six weeks, during which time the concrete gradually disintegrated. When it became evident that this collector also was failing, the firm decided that this problem was not suitable for their type of collecting equipment and made arrangements to move the

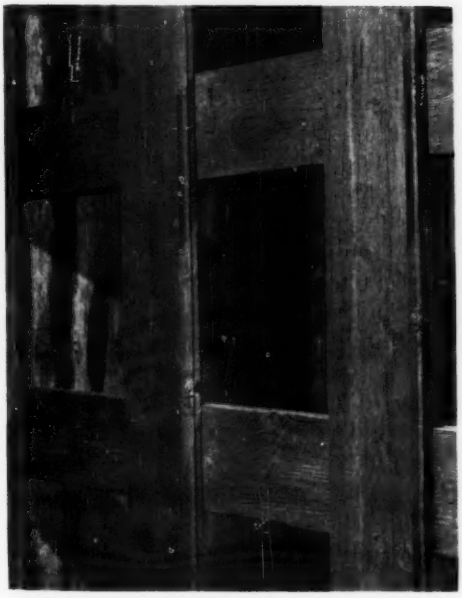


Fig. 6.
View of straighteners near exhaust of dust collector.

collector back to their factory. Meanwhile, the lightweight aggregate company, which was producing approximately 25% of all of the lightweight aggregate in this country, was still faced with the original serious problem and needed an immediate solution.

In order to give some idea of the magnitude of the collection problem, the following information will be of value. The volume of gas given off by the six kilns was approximately 50,000 cubic feet of effluent per minute at a temperature of 400° to 500° F. Enough sulfur was present in the combustion products of the 100 tons of coal consumed daily to produce 6900 pounds of sulfuric acid. This calculation assumed that only three-quarters of the sulfur was oxidized to sulfur dioxide and sulfur trioxide and consequently converted to acid, and also that the coal contained only 1½% sulfur. From effluent samples collected, it was estimated that 50 tons of dust (about 16.9 grains per cubic foot of effluent) were dispersed in the atmosphere in a 24 hour period.

After considerable thought, research, and planning, the company decided to build its own collector in an effort to eliminate the air pollution problem. This collector was built of wood treated with Walman Salts to make it heat and acid-resistant. The wooden structure itself was 15 feet high and 15 feet wide, mounted on a concrete base about 18 inches high and 50 feet long. No nails were used inside this structure because of the corrosive action of the gas. Wooden pegs were used to hold the three by twelve inch (3" x 12") treated fir planks in place. The poured concrete floor of the collector sloped toward the center where a drain was located. Two fans, each exhausting the effluent from three kilns, were located in the ductwork a short distance ahead of the collector (Fig. 4). These in turn exhausted through two inlet ducts near the top at one end of the collector. A series of baffles as shown in Fig. 5 were built inside the collector to guide the gases in the desired pattern. The distance between the baffles varied from six feet to eight feet, six inches. One series of baffles had a five foot wide vertical opening in the center, while

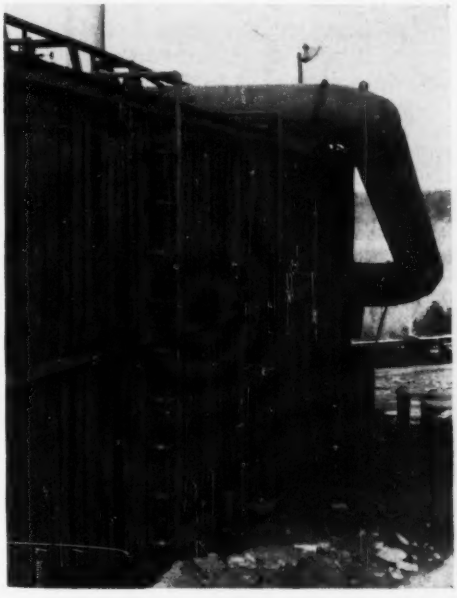


Fig. 7.
Side view of dust collector showing location of spray nozzles and a duct to one of the fans.

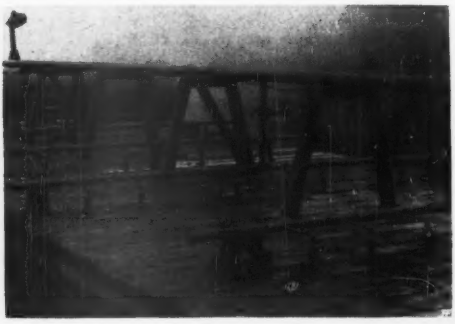


Fig. 8.
Top view of dust collector showing main and distribution water lines with spray nozzles attached.

the other series had a two foot, six inch wide vertical passage at each side of the dust collector. Near the outlet end of the collector there were two sections of straighteners (Fig. 6) followed by an exhaust stack six feet, six inches deep, nine feet wide and fifteen feet high to discharge the cleaned effluent into the atmosphere. The schematic view (Fig. 5) shows the path of the kiln gases through the dust collector.

Two series of different type nozzles were located so that the spray wet the dust and cooled the gases. The nozzles across the top of the structure were used to produce a fog, while those along the side gave a fan-shaped spray (Figs. 7 and 8). It should be noted that one bank of nozzles was in the top of the structure very near the inlet ducts. These nozzles were probably the most important of any group since the gases at this point were at least 400° F. and most of the water spray was vaporized immediately. This vaporization greatly increased the efficiency of wetting small particles.

To obtain an adequate water supply for the 150 nozzles, a half mile of four inch water line was laid to a nearby stream. A storage tank and booster pump were also necessary to supply approximately 325 gallons of water per minute at a minimum pressure of 40 pounds per square inch at the nozzles.

At first, the spray nozzles had metal holders extending into the walls and roof of the collector, but since these corroded, they were replaced by new-design plastic holders which could be removed and serviced without shutting down the collector (Figs. 9 and 10). This type proved very satisfactory and did not corrode. The nozzles, themselves, did not corrode and only occasionally needed cleaning after a severe wash of debris and dirt into the water supply (Fig. 11).

After the collector had been in operation for a short time, a series of tests were made to determine how satisfactorily it was operating, even though there appeared to be

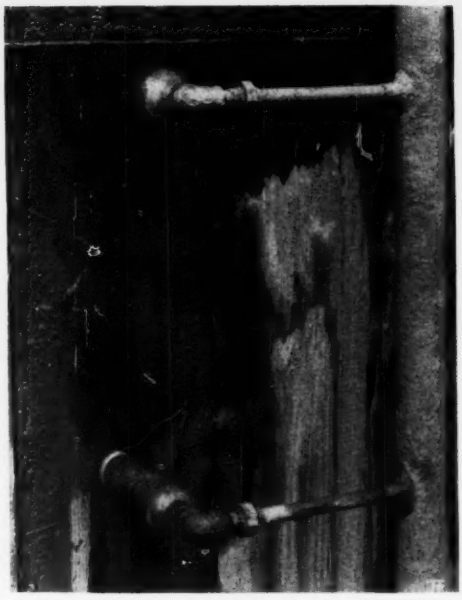


Fig. 9.
Close up of spray nozzles in side of dust collector.

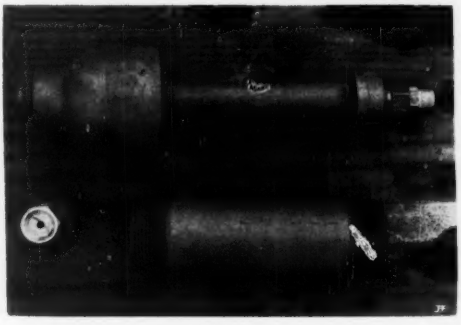


Fig. 10.
Disassembly of plastic nozzle holder.

Fig. 11.
Interior view of spray nozzle protruding through sidewall.

very little dust being dispersed into the atmosphere. Before the collector was put into operation, the effluent from the kiln stack was a reddish brown color. When the dust collector was used, the effluent was white and disappeared shortly after leaving the exhaust stack since much of the visible portion was water vapor. There was no detectable amount of carbon monoxide found in the exhaust gases. Tests also showed that there were 2.2% to 3.2% of carbon dioxide and 11% to 14% of oxygen present. Analyses for sulfur dioxide in the exhaust stack revealed the presence of 58 parts of sulfur dioxide per million parts of air. However, there was no noticeable concentration at ground level and the vegetation near the plant had shown no effects from this gas. Evidently there was sufficient dilution after the gas left the collector to eliminate the problem. The gas from the kilns contained approximately five parts of hydrogen sulfide per million parts of air, while in the gas in the collector exhaust stack no detectable amount was found. The pH of the exhaust gas was found to be 3.25. There was some variation in the data obtained because of the changes in controls made by workers operating the kilns.

The pH of the water supply was found to be 5.0, while the water coming from the

Fig. 12.
Inside view of dust collector showing partial disintegration of concrete foundation. Note wooden portion of collector not affected.

collector had a pH of 3.5. The State in which the plant was located had fairly strict stream pollution laws. Therefore, that problem was investigated quite thoroughly. A settling basin had been built in a hollow beside the plant. At a distance of 200 feet downstream from the overflow of the settling basin, the pH of the water was 4.0. Since this water had at least one mile to go before joining the river, there was not much danger of any adverse effects on aquatic life after it reached the river.

Stack samples were also taken for the total amount of solids suspended in the exhaust gas. These values were found to be 0.339 grains per cubic foot of gas at 120° F. This dust loading was less than the permissible limit in many city codes. A particle size determination was also made on the solids in the stack effluent and the median size particle was 1.0 microns. The composite of all of the samples showed 90% were under 2.0 microns. From the data cited, it can be readily seen that this nuisance problem was virtually eliminated.

After this collector had been in continuous operation 24 hours a day for six months, it was decided to build a duplicate collector so that if anything happened to the one collector, it would not be necessary to shut down the plant. This second collector was built next to the first one and the ductwork arranged so that by using three identical fans, either collector could be used. The blades on the fans had to be changed about every eight months because of the abrasive action of the dust.

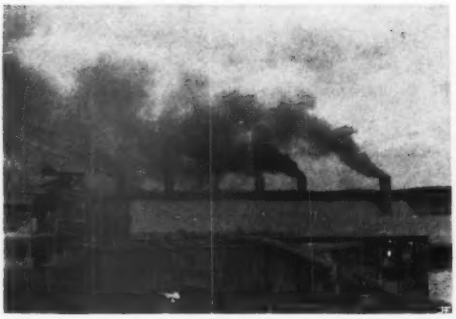


Fig. 13.
View of exhaust gases from the steel stacks. Dust collector in foreground not operating.

Fig. 14.
View showing discharge of gases from dust collector. Note two collectors side by side.

After the first wooden collector had been in continuous operation for 18 months, the second collector was cut in and the first one was inspected for wear. The wooden portion of the collector was in excellent condition but the concrete foundation needed repairs. It will be noted in the illustration (Fig. 12) that the surface of the concrete was worn away probably due to both corrosive and errosive actions of the effluent. This wearing away occurred only near the inlet end of the collector as might be expected. Although this condition was not serious, it was decided to repair the concrete foundation and cover it with a protective coating. One of the nice features of the collector was that it was self cleaning. Even after a year and a half of operation, there was no accumulation of solid material in the collector. The pictures showing the effluent from the steel kiln stacks (Fig. 13) and from the exhaust stack (Figs. 14 and 15) on the collector illustrate the reduction in the dust dispersion. Without the collector being used, approximately 50 tons of dust was emitted in a 24 hour period.

Furthermore, there have been no complaints since the collector was put into operation, even though some of the original complainants painted their houses white last summer. This example illustrates what a plant can do, even though it is a new operation, if it is seriously concerned with its responsibilities in public relations.

Fig. 15.
Overall view of plant from south showing exhaust discharge from dust collector, settling basin, and water outlet from collector.

Summary

THE LIGHTWEIGHT aggregate industry is comparatively new and in the production of this material the emission of atmospheric dust can be a serious problem. The amount of effluent from the kilns of the plant described was approximately 50,000 c.f.m. Although several collectors were tried, including one commercial wet type, none of them operated successfully for more than a few weeks because of the abrasive action of the dust or the sulfur content of the gas. The temperature of the effluent from the kilns was approximately 500°F. In order to adequately control the dust from the kiln, a dust collector built of specially treated wood for resistance to heat and acid was constructed. A series of baffles and nozzles were installed to increase the collection efficiency. Over 90% of the atmospheric dust was eliminated and no complaints have been received since this collector was put into operation.

Problems Associated with

The Application of External and Internal Radiation Exposure Limits

KARL Z. MORGAN, Ph.D., Health Physics Division
Oak Ridge National Laboratory, Oak Ridge, Tennessee

FROM THE EARLY beginning of work with ionizing radiation there has been the problem of coining useful units and making certain that they are used properly. Some of the early units for ionizing radiation such as the "erythema dose" were as unsatisfactory and unreliable as the early electrical unit which purported to measure current by the motion it induced from a voltage applied to the nerve in a frog's leg. The erythema unit was not a good choice because of the large variation in human susceptibility to erythema and because of the energy dependence—the roentgen dose required to produce an erythema is much less for 50 KV x-rays than for 1 Mev x-rays. These two complicating factors, i.e., human variability and energy dependence, continue even today to present difficulties in radiation dosimetry.

One of the earliest and more commonly used units of ionizing radiation is the roentgen. This unit is intended to measure the damage produced in soft tissue by ionizing radiation and is a compromise between theoretical requirements and a property of radiation that is reproducible and can be measured conveniently. From the definition of the roentgen and as a result of the behavior* of radiation in its passage through air, it may be stated that the roentgen corresponds to 1 esu of charge produced in 1 cc of air (at 0° C and 760 mm Hg pressure) by secondary electrons originating from the interactions of primary x- and γ-radiation (energy from a few Kev to about 3 Mev) in a surrounding air wall of equilibrium thickness. Some of the limitations of this unit may be summarized as follows: (1) it applies only to x- or γ-radiation of energy sufficient to produce ionization in air but low enough that the secondary electrons dissipate their energy in the medium in the neighborhood of their origin; (2) it refers to esu produced in air rather than in tissue; and (3) it refers to esu per cc of air rather than ergs/g of tissue. Some of these difficulties are avoided by the use of the rep and the rad which are units of absorbed energy. The rep corresponds to an absorbed dose of 93 ergs g of tissue and the rad corresponds to an absorbed dose of 100 ergs/g of any medium. Both units apply to any type of radiation which directly or indirectly produces ionization, i.e., β-rays and protons produce ionization directly while γ-rays and fast neutrons produce ionization indirectly by way of secondary electrons and the recoil atom respectively. Difficulties arise in the use of these units; for example, there is no certainty that the damage is proportional to the energy absorbed in tissue and even if it were, in present-day dosimetry perhaps the best that can be accomplished is to measure the ion pairs produced in a tissue equivalent chamber. In converting this measurement to rep or rad units the Bragg-Gray principle must be applied in which case a knowledge of the relative mass stopping power (P) and the electron volts to produce an ion pair (w) is required. For the Bragg-Gray principle to apply not only must both of these quantities, i.e., P and w,

Presented at the Sixteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Buffalo, New York, April 28, 1955.

*This practical application of the roentgen is possible because the esu produced in air by secondary electrons originating in 0.001293 g of air (1 cc air at 0°C and 760 mm Hg) is equal to the esu collected in 0.001293 g of air which are produced by secondary electrons originating in the surrounding air wall of equilibrium thickness (≅ range of secondary electrons).

be known, but they should be relatively independent of energy and of the physical state of the medium. Our knowledge of P and w is sufficient for approximate dosimetry in the common energy range, but unfortunately both P and w are somewhat dependent on the energy as well as upon the type of radiation and the atomic number of the medium and P for heavy particles seems to be a function of the physical state of the medium.[1] Also there is good reason to suppose that radiation damage depends on the differential stopping power or linear energy transfer (LET) of the radiation in tissue and information relative to this relationship is not readily available and difficult to obtain experimentally with practical dosimetry since the differential values of LET may be changing constantly along the path of each ionizing particle. Usually one must be satisfied with a measurement of the rep or rad in tissue for each type of radiation, i.e., α, β, n, etc., and obtain the total dose in rem units by applying a single relative biological effectiveness (RBE) for each type, i.e., rem = $(RBE)_{\alpha} \times (rad)_{\alpha} + (RBE)_{\beta} \times (rad)_{\beta} + (RBE)_{n} \times (rad)_{n} + \ldots$ etc. Hurst[2] has developed a method of dosimetry using threshold detectors which enables one to measure the LET associated with the neutron absorbed dose and perhaps similar techniques can be applied to other types of radiation. In the use of the rem unit it must be kept in mind that RBE differs for the various types and degrees of radiation damage, and in some cases is a function of the dose rate.[3] Although it has not been proved, there is good reason to believe that there is an LET that corresponds to a maximum RBE for each type of radiation damage. For example, if it requires 200 ion pairs per μ of tissue in the region of interest to produce a certain biological damage, it follows that the RBE of a high energy ionizing particle would increase as its energy decreased until S = LET/w = 200 ion pairs/μ of tissue and would decrease at lower energy where S is greater than 200 ion pairs/μ of tissue. It is sometimes assumed or implied that the ionization per se is responsible for all the damage from ionizing radiation. This, however, may be far from the truth since nuclear collisions, molecular and atomic excitations, and various other forms of energy transitions may make an important contribution to the damage.

There has been considerable confusion in the use of the terms "dose" and "absorbed dose." The International Commission on Radiological Units has made a distinction between these two terms by defining the dose as a quantity of radiation passing through unit area perpendicular to the beam or the time integral of intensity, i.e., ergs/cm^2, and absorbed dose as the amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It should be pointed out that most of the literature uses the word "dose" to refer to what is now officially defined as "absorbed dose" and the confusion is by no means removed by having an official definition of "absorbed dose" since even today most writers continue to use "dose" when they mean "absorbed dose." In any case, only the present official definitions are used in this discussion and absorbed dose is given in rep and rad units or in terms of ergs/g. On this basis the roentgen is neither a "dose" nor an "absorbed dose" unit, however, if the average value of w is known it is related to the "absorbed dose" by the equation

$$1 \text{ roentgen} = \left[1 \text{ (esu/cc)} \frac{1}{\rho_a} \text{ (cc/g)} \frac{1}{4.8 \times 10^{-10}} \text{ (ip/esu)} \text{ w(ev/ip)} \; 1.6 \times 10^{-12} \text{ (ergs/ev)} \frac{1}{100} \text{ (g rad/ergs)} \right] \approx 0.9 \text{ rad in air if w} = 35 \qquad (1)$$

It should be noted that the rad is a unit of absorbed dose in any medium and, therefore, the medium in which the rad is measured should be specified, and that the roentgen relates to the "absorbed dose" in air while the rep is a unit of "absorbed dose" in tissue.

Another unit that is sometimes carelessly used in defining radiation exposure limits and that deserves discussion here is the curie. This unit was originally defined as that amount of radon in equilibrium with 1 g of Ra^{226}. At present it is defined as that amount of any radionuclide that disinte-

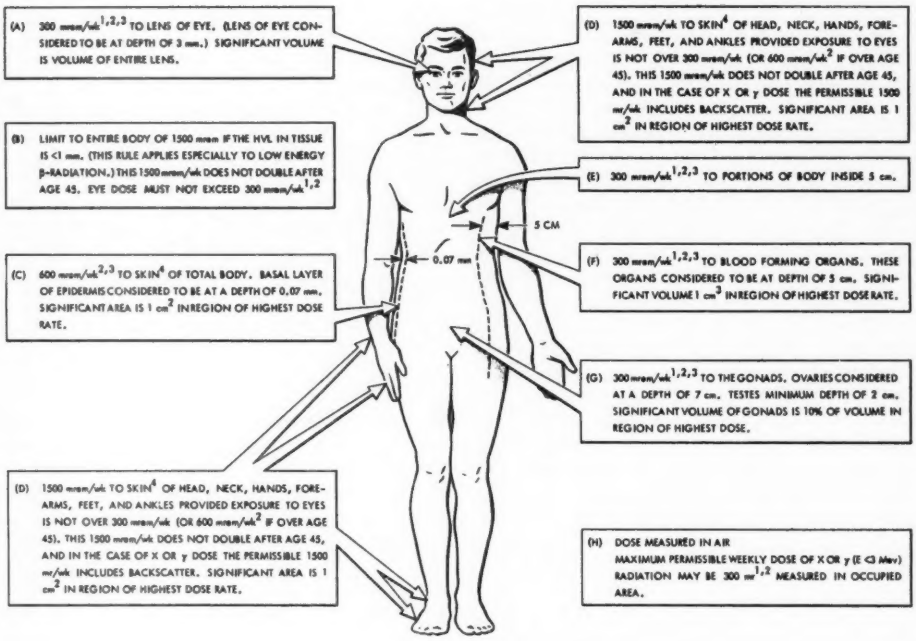
grates at the rate of 3.700×10^{10} disintegrations per second. One gram of Ra^{226} in equilibrium with its radon daughter corresponds, according to the new definition, to about 3.6/3.7 curies. In referring to a curie, or a fraction thereof, of a radionuclide that has one or more radioactive daughters it is usually necessary to be specific and indicate the fraction of equilibrium of each of the daughter products. In the most recent published tables of maximum permissible concentration, MPC, and maximum permissible body burden, q, of the radionuclides,[4] values are given for parent-daughter pairs such as $Sr^{90} + Y^{90}$, $Ba^{140} + La^{140}$, etc., but in these cases it is stated specifically that the values of MPC refer to $\mu c/cc$ of the parent i.e., Sr^{90}, Ba^{140}, etc., taken into the body in air or water and the q refers to μc of the parent deposited in the total body following an exposure for 70 years. It is assumed that the daughter products accumulate while the parent isotope is in the body and reach transient equilibrium with the parent unless the radioactive half life of the daughter is a large fraction of 70 years. Therefore, although it is assumed none of the daughter products are present during inhalation or ingestion of the parent, the growth of the daughters in the body is responsible for reducing the values of MPC and q as listed in the ICRP Handbook[4] and the NCRP Handbook-52.[5] If the daughter is present initially in the air or water, the resulting $(MPC)_{pd}$ of the parent and daughter mixture is given by the equation:

$$(MPC)_{pd} = a_p(MPC)_p + a_d(MPC)_d + \ldots . \quad (2)$$

in which $a_p + a_d + \ldots . = 1$, a_p, a_d are the fractions of the respective (MPC's) for the parent and daughter based on the same body organ. In the case of Ra^{226} values are given in the ICRP Handbook[4] for Ra^{226} + 55% of daughters. This may be defined as meaning that MPC and q are given for pure Ra^{226} taken into the body where a portion is deposited in the bone and the daughter products (down to RaD) reach 55% of equilibrium contributing 55% of their energy to the absorbed dose. Because of the long half life of RaD, it together with its daughters (RaE and RaF) contribute only 1.5% of the total dose to the bone over a 70-year exposure period. The values in the ICRP Handbook[4] for natural uranium, natural thorium, and Rn^{222} are exceptions to the above general rules in that, when referring to MPC and q, one curie of natural uranium means 2.03 curies, i.e., 3.7×10^{10} dis/sec of U^{238}, 3.7×10^{10} dis/sec of U^{234}, and 9×10^{8} dis/sec of U^{235}, and one curie of natural thorium means 2 curies, i.e., 3.7×10^{10} dis/sec of Th^{232}, and 3.7×10^{10} dis/sec of Th^{228}. One curie of Rn^{222} means 5 curies, i.e., 1 curie each of Rn, RaA, RaB, RaC, and RaC'.

Basic Criteria of Permissible Exposure

THERE are two basic criteria of permissible exposure to ionizing radiation: (1) an absorbed dose rate of not more than 0.3 rem/wk to the critical body tissue, and (2) a body burden of radioisotopes that delivers an absorbed dose to the bone which is not more than that delivered by 0.1 μg of Ra^{226}. Both of these criteria are applied to the calculation of the maximum permissible concentration in air and water, $(MPC)_a$ and $(MPC)_w$, and the permissible body burden, q, of radioactive material deposited inside the body, but usually only the first criterion is related to permissible external exposure. Fig. 1 indicates the maximum permissible exposure of various portions of the body to ionizing radiation from an external source as discussed in detail in the National (U.S.)[6] and International[4] Handbooks. The basic absorbed dose rate has undergone two major reductions during the past two decades. First, it was 0.2 r/day (or 1 r/wk)[7]; then it was reduced to 0.1 r/day (or 0.5 r/wk)[8] and recently[4,5,6] it was reduced to 0.3 rem/wk with the provision that in certain cases the absorbed dose rate could be increased to 0.9 rem/wk provided the total absorbed dose in 13 weeks does not exceed 3.0 rem. This 25% penalty in the 13-week exposure when the 0.3 rem/wk rate is exceeded has served the useful function in our Laboratory (ORNL) of discouraging the practice of exceeding the basic exposure rate. There are no human experiences or animal experiments that establish strong support of the 0.3 rem/wk value. It is believed that the average exposure of radiologists during the past two decades has exceeded this value considerably—perhaps by a factor of 10—and there is irrefutable evidence that many of them have been damaged in that the incidence of leukemia in


(A) 300 mrem/wk[1,2,3] TO LENS OF EYE. (LENS OF EYE CONSIDERED TO BE AT DEPTH OF 3 mm.) SIGNIFICANT VOLUME IS VOLUME OF ENTIRE LENS.
(B) LIMIT TO ENTIRE BODY OF 1500 mrem IF THE HVL IN TISSUE IS <1 mm. (THIS RULE APPLIES ESPECIALLY TO LOW ENERGY β-RADIATION.) THIS 1500 mrem/wk DOES NOT DOUBLE AFTER AGE 45. EYE DOSE MUST NOT EXCEED 300 mrem/wk[1,2]
(C) 600 mrem/wk[2,3] TO SKIN[4] OF TOTAL BODY. BASAL LAYER OF EPIDERMIS CONSIDERED TO BE AT A DEPTH OF 0.07 mm. SIGNIFICANT AREA IS 1 cm² IN REGION OF HIGHEST DOSE RATE.
(D) 1500 mrem/wk TO SKIN[4] OF HEAD, NECK, HANDS, FOREARMS, FEET, AND ANKLES PROVIDED EXPOSURE TO EYES IS NOT OVER 300 mrem/wk (OR 600 mrem/wk² IF OVER AGE 45). THIS 1500 mrem/wk DOES NOT DOUBLE AFTER AGE 45, AND IN THE CASE OF X OR γ DOSE THE PERMISSIBLE 1500 mr/wk INCLUDES BACKSCATTER. SIGNIFICANT AREA IS 1 cm² IN REGION OF HIGHEST DOSE RATE.
5 CM
0.07 mm
(D) 1500 mrem/wk TO SKIN[4] OF HEAD, NECK, HANDS, FOREARMS, FEET, AND ANKLES PROVIDED EXPOSURE TO EYES IS NOT OVER 300 mrem/wk (OR 600 mrem/wk² IF OVER AGE 45). THIS 1500 mrem/wk DOES NOT DOUBLE AFTER AGE 45, AND IN THE CASE OF X OR γ DOSE THE PERMISSIBLE 1500 mr/wk INCLUDES BACKSCATTER. SIGNIFICANT AREA IS 1 cm² IN REGION OF HIGHEST DOSE RATE.
(E) 300 mrem/wk[1,2,3] TO PORTIONS OF BODY INSIDE 5 cm.
(F) 300 mrem/wk[1,2,3] TO BLOOD FORMING ORGANS. THESE ORGANS CONSIDERED TO BE AT DEPTH OF 5 cm. SIGNIFICANT VOLUME 1 cm³ IN REGION OF HIGHEST DOSE RATE.
(G) 300 mrem/wk[1,2,3] TO THE GONADS. OVARIES CONSIDERED AT A DEPTH OF 7 cm. TESTES MINIMUM DEPTH OF 2 cm. SIGNIFICANT VOLUME OF GONADS IS 10% OF VOLUME IN REGION OF HIGHEST DOSE.
(H) DOSE MEASURED IN AIR
MAXIMUM PERMISSIBLE WEEKLY DOSE OF X OR γ (E <3 Mev) RADIATION MAY BE 300 mr[1,2] MEASURED IN OCCUPIED AREA.

(1) THE 300 mr/wk OF X OR γ RADIATION MEASURED IN AIR (WHEN E < 3 Mev) MAY BE INCREASED TO 450 mr/wk TO THE LENS OF THE EYE, AND ABOUT 400 mr/wk TO THE BONE, AND TO OTHER TISSUE MORE THAN 5 cm INSIDE THE BODY WITH EXCEPTION OF THE GONADS WHICH ARE LIMITED TO 300 mrem/wk UNTIL AFTER AGE 45.

(2) TOTAL BODY DOSE RATE (INCLUDING DOSE RATE TO THE GONADS) MAY BE DOUBLED AFTER AGE 45 PROVIDED THE LENS OF THE EYES DO NOT RECEIVE >300 mrem/wk FROM RADIATION OF HIGH SPECIFIC IONIZATION AND >600 mrem/wk TOTAL DOSE.

(3) AN ALTERNATE RULE IS APPLICATION OF RULE (H) TO MEASUREMENT OF X OR γ DOSE IN AIR.

(4) SEE FIGURE 2 FOR DOSE DISTRIBUTION BELOW SKIN.

Fig. 1.
Basic permissible exposure rates to external sources of ionizing radiations.

this group is about nine times that among medical men that are not radiologists.[9] Although there is no way of knowing how safe the present basic permissible rate of 0.3 rem/wk really is, it is certain that it should not be averaged over a large fraction of a life span. It should be noted that if the basic exposure rate as outlined in Fig. 1 were permitted for the lifetime of an individual, the critical body organs would accumulate an absorbed dose of 1200 rem, the skin 2400 rem and the appendages of the body 4200 rem. It is impossible at present to assess accurately the damage to an individual who accumulates such a large absorbed dose. It seems likely that such exposure would increase the probability of leukemia and other forms of cancer, that it might result in an increased incidence of cataracts, that it would shorten the average expected life span by about 10%; and, if a large fraction of the population received this exposure, it could increase the number of mutations by several orders of magnitude, perhaps resulting in serious consequences to the human race. Certainly we, as health physicists, agree that such accumulation of absorbed dose is undesirable, that probably all radiation exposure is harmful to some degree, and that our goal should be

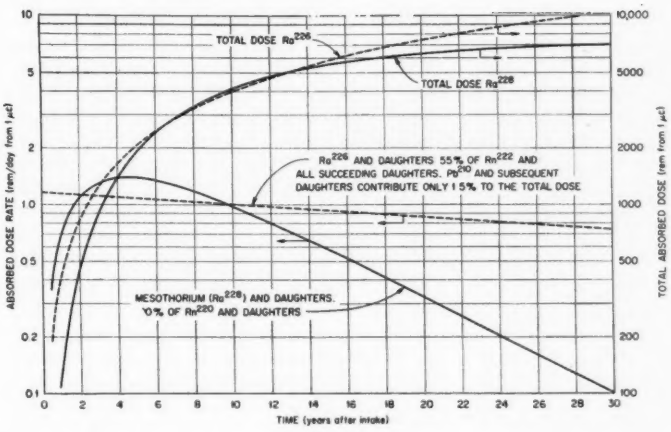

TOTAL DOSE Ra^{226}
TOTAL DOSE Ra^{228}
Ra^{226} AND DAUGHTERS 55% OF Rn^{222} AND ALL SUCCEEDING DAUGHTERS. Pb^{210} AND SUBSEQUENT DAUGHTERS CONTRIBUTE ONLY 1.5% TO THE TOTAL DOSE
MESOTHORIUM (Ra^{228}) AND DAUGHTERS. 10% OF Rn^{220} AND DAUGHTERS
ABSORBED DOSE RATE (rem/day from 1 μc)
TOTAL ABSORBED DOSE (rem from 1 μc)
TIME (years after intake)

Fig. 2.

to permit no unnecessary exposure where a reasonable expenditure of time and money will prevent it.

One may ask what is a reasonable expenditure to reduce radiation exposure to the lowest possible value? The answer can be more easily given than interpreted; namely, "A reasonable effort is one that reduces the hazard from ionizing radiation to the same order of magnitude as other hazards with which we are accustomed—overeating, lack of rest, dusty homes, etc." The difficulty with this answer is that at present we do not have sufficient biological information adequately to appraise the consequences of chronic radiation exposure of man. Only time and accurate exposure records will permit us to state whether or not 10 rem, 100 rem or 1000 rem received between ages 30 and 40, for example, will result in serious damage at the age of 80.

Not only may one question the basic exposure rate of 0.3 rem/wk as a safe and reasonable reference standard but also the criteria that limits the damage to not more than that received from a body burden of 0.1 μg of Ra^{226} deserves equal scrutiny. Many researchers[10] have investigated this matter and it appears that the factor of safety in this figure is not greater than five and may be less than one. On June 13 and 14, 1951, a meeting was called in New York of persons in the United States that were originally responsible for selecting this reference value of 0.1 μg of Ra^{226} and of others who had studied this problem. Ostensibly the purpose of this meeting was to review the more recent surveys of persons having large body burdens of Ra^{226} and to determine whether or not the 0.1 μg value could be increased in light of the lack of body damage at this level and in view of the fact that recent evidence indicated that many persons—especially the radium dial painters—who now have large body burdens of Ra^{226} may have carried initially large burdens of mesothorium (Ra^{228}). If a person initially carried 100 μc of radium composed of 10 μc of Ra^{226} and 90 μc of Ra^{228} and if 10 years later measurements were made only of the Ra^{226} remaining in the body the integrated absorbed dose (neglecting the contribution of Ra^{228} and its daughters) would be underestimated by a factor of 10. At first thought one might suppose that the underestimation from the neglect of Ra^{228} would be much less because Ra^{228} has a half life of only 6.7 years compared to that of Ra^{226} of 1630 years. However, Burnett[11] has shown in Fig. 2 that the average absorbed dose rate and the integrated absorbed dose over a 15-year period are essentially the same whether from an initial body burden of 1 μc of Ra^{226} or from 1 μc of Ra ^{228}. This is a result of the block in the Ra^{228} chain beginning with the 1.9 year Th^{228} and the block of the 22 year Pb^{210} in the Ra^{226} chain. In addition, this results from the fact that Rn^{220} has a short half life of only 54 sec compared to the half life of Rn^{222} of 3.8 days, permitting Rn^{220} and all its daughters to contribute their energy to the absorbed dose compared to a 55% contribution to the absorbed dose from Rn^{222} plus its daughter products down to Pb^{210} and a 1.5% contribution from Pb^{210} and its daughter products. The neglect in estimating the body burden of Ra^{228} might cause an even greater underestimate of the radiation damage if thorium deposits in a portion of the skeleton where it produces greater

damage per μc than does radium. In other words, the Th^{228} daughter of Ra^{228} could be an important contributing factor to the damage if it delivers its absorbed dose to a more radiosensitive portion of the bone or it may have a greater non-uniform distribution factor than radium—resulting in more localized damage. This fact remains to be proved; however, it might be pointed out that the ICRP Handbook[4] assumes thorium to be less harmful rather than more harmful per μc than radium because of the many years of experience man has had working with thorium and thoratrast, supposedly with relatively slight radiation damage. More thorough and searching surveys (by Looney[10]) of persons with a body burden of thorium are now in progress and there is some evidence to indicate that thorium may be a greater radiation hazard per μc than radium. If this proves true, it may further explain the high incidence of radiation damage among radium dial painters and indicate that the present MPC and q values for thorium should be reduced.

At this New York Conference on Radium the radium exposure data[12] of the Elgin State Hospital patients who had received a known quantity of Ra^{226} with little or no Ra^{228} was reviewed and their present body burden of Ra^{226} was compared with the initial amount of Ra^{226} administered. The integrated exposure was correlated with the changes in bone structure—striations and areas of increased and decreased bone density—which were observed on roentgenographic film. It was not known whether such changes in bone structure represent damage in the sense that detectable harm has resulted to these persons, but it was evident that some persons with present body burdens as low as 0.1 μg of Ra^{226} have an increased incidence of these bone changes which may be the first stages leading to bone damage. More recently this same group[12] has examined many other persons having body burdens of Ra^{226} and these data seem to justify the decision of the New York Conference on Radium to recommend no change in the 0.1 μg value as a permissible body burden of radium. Thousands of people who received radium by accident and for medical treatment during the past 25 years now carry body burdens of Ra^{226} and Ra^{228} that range from 1/10 to 100 times the 0.1 μc value; all of whom originally had much larger body burdens. Although some of them at or near the 0.1 μc value show changes in bone structure and perhaps a few other biological changes, there is no evidence that this 0.1 μc level is damaging—especially would this be true had the body burden been maintained at the 0.1 μc value rather than decreased by a factor of perhaps 100 from the value at the onset of exposure 20 to 25 years ago. Therefore, although we do not believe that a body burden of 0.1 μg of Ra^{226} maintained in man over 70 years would be harmless it seems likely that it would not result in readily detectable damage. There remains, of course, the possibility that although 0.1 μc of Ra^{226} or Ra^{228} is relatively harmless as a body burden over a period of 20 years, the observed damage, e.g., carcinogenesis, may increase with the square or the cube of time of exposure, and if such should prove to be the case a lower permissible body burden will have to be set when applied to the life span of man. This word of warning is added merely to emphasize the great importance of continuing to study the human population that has an appreciable body burden of Ra^{226} and/or Ra^{228}. In fact this same advice applies to all radioactive materials and in particular to natural Th and natural U. There is no substitute for reliable human data to substantiate the efficacy of the reference standards of acceptable exposure to ionizing radiation.

Other Criteria of Permissible Exposure

AS EXPLAINED above the two reference standards or basic criteria of permissible exposure, i.e., 0.3 rem/wk and the equivalent body burden of 0.1 μc of Ra^{226} or Ra^{228} are established by many years' observation of the effects of exposures of this magnitude (and greater) on man. These are not the only human exposure values that can be used as standards of reference in setting maximum permissible external exposure values and in establishing MPC and q values for the various radioactive materials. There is a considerable amount of data on human exposure to natural Th and natural U from operations of mines and chemical plants, and from medical application during the past 30 years. Unfortunately, poor records, if any, of the exposures were maintained, but it is safe to say that

the air contamination of many of the operations far exceeded the present MPC values for U, Th, Ra^{226}, and Rn^{222}. Perhaps more careful and extended studies of these exposures will yield more reliable data.

One source of useful human exposure data is that furnished from accidents or as a result of military operations. Some useful data on cataractogenesis, carcinogenesis, leukemia incidence, reduction in fertility, genetic changes, etc., are being accumulated from Hiroshima and Nagasaki but most of those changes have been observed only among the survivors who received very large absorbed doses of radiation. The estimates of absorbed dose are complicated by uncertainties in the position of the person at the time of exposure, the amounts of shielding and scattered radiation and the relative mixture of γ and n radiations. In addition, blast damage, thermal burns and exposure to the weather influenced the radiation syndrome. Continued studies of the survivors may make it possible to set a limit of absorbed dose below which certain of these effects would not be observed but it is unlikely that much quantitative data will be obtained to aid in establishing safe absorbed dose rates for chronic exposure. For types of radiation damage that vary linearly (Fig. 3) with the absorbed dose, e.g., genetic mutations, shortening of life span and perhaps the incidence of certain types of tumors, it may be possible to collect human data which will be very useful in setting a maximum permissible accumulated absorbed dose for man during a lifetime.

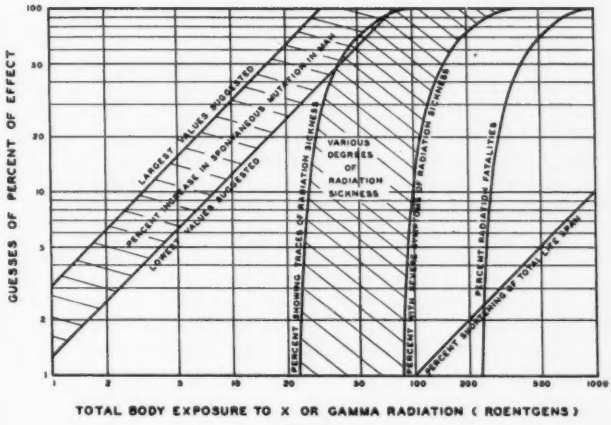


Fig. 3.

The recent accidental exposure of U.S. personnel, natives and Japanese fishermen during the A-bomb test in the South Pacific in which radioactive fallout subjected them to high absorbed doses of both soft and hard radiations should shed some light on permissible exposure but again the estimates of absorbed dose, especially the contribution of the soft γ and β radiation, make it difficult to set down numbers that can be extrapolated to conditions of low-level chronic exposure. Similarly, various other radiation accidents, e.g., the two fatal accidents at Los Alamos and the critical assembly incident of the Argonne National Laboratory, have been and are still being studied in order to glean all possible information on the relative damage of various types of radiation, the threshold absorbed dose (see Fig. 3) for certain types of radiation damage, and the possible appearance of late effects of radiation. It would be extremely worth-while if more people who are potential victims of large accidental exposure wore adequate film meters. This is one argument for the type of film badge service used at our laboratory (ORNL) where the film badge is a part of the security badge and is worn to and from the laboratory by all employees. It would be a comparatively small expense and I believe very worth-while if everyone wore a radiation monitoring meter as a part of his identification tag. Such a meter if used in large numbers would cost less than $1.00 a year per person for servicing and maintenance. In addition to being available to furnish useful exposure data in case of accident, it could be a great aid in civil defense, and if worn during medical and dental exposures it could serve as a means of recording the accumulated absorbed dose during a lifetime.

Another means of obtaining human exposure data to serve as criteria of permissible exposure would be to give human

volunteers external exposure to mixtures of various types of ionizing radiation at various rates and with various rest intervals between exposures. Such exposures should be well below what is believed to be a safe value. The same type of experiments could be conducted with radioactive materials administered by ingestion, inhalation, injection and absorption through the skin. If such experiments should be undertaken they must be carefully supervised and carried out only when the exposed volunteers have complete knowledge of the likely consequences of what is being done and there is a system of "checks and double checks" to make certain that the experiments are conducted only on a completely voluntary and scientific basis. In some cases "life termers" in penal institutions might consider it an opportunity to pay back some of their debt to society by taking part in such experiments but again it must be made absolutely certain that there is no pressure or compulsion and that the persons exposed do so and continue to do so only on a completely voluntary basis. In some instances prison sentences might be reprieved or portions of sentences suspended as a reward for such contributions to research, especially if exposures are extended into the range where damage is expected or actually develops. In all these experiments every effort should be made to obtain autopsy data when those cooperating in this experiment expire.

A similar but much less involved program could be set up immediately in which tracer quantities of the less dangerous radionuclides—in quantities far below the estimated MPC and q values—are administered to volunteers. In case of the more dangerous radionuclides one may substitute less dangerous, short-lived isotopes, e.g., the γ emitting Sr^{85} with a half life of 65 days may be substituted for the more dangerous β-emitting Sr^{90} with a half life of 20 years. In these experiments considerable useful data can be obtained by analysis of the urine, feces and blood, and, if some of the volunteers are terminal patients, an analysis of autopsy data will furnish additional vital information.

One of the most promising approaches to the problem of obtaining human data for the establishment of MPC and q values is the program supported by our laboratory (ORNL)[13] in which the element distribution in the body is determined by spectographic analysis of human tissue. Samples of human tissue from the various body organs of hundreds of persons from all parts of the United States who have died a violent death are being examined spectrographically. Persons dying a violent death are preferred in order to avoid the perturbations caused by long illness or by drugs. The tissue is being collected from many parts of the United States and a few samples from abroad in order to determine whether or not there are geographical differences. Such data not only makes it possible to obtain a good basis for establishing the element distribution in the standard man[4] but, since the stable element follows the same distribution pattern in the body as radioisotopes of the same element — provided the chemical form of the material taken into the body is the same in both cases—it follows that this analysis furnishes direct evidence of the pattern of distribution of the various radioisotopes. The body organ receiving the greatest concentration of a radionuclide is usually the critical organ. (Actually the critical body organ is that organ of the body receiving the radionuclide that results in the greatest damage to the body and as a consequence in about 1% of the cases it is not the organ with the greatest concentration.) In addition, when typical samples of food are analyzed one has a means of obtaining the biological half life T_b under equilibrium conditions by substituting experimental values in the equation:

$$T_b = \frac{0.693\ mc}{If_w} \qquad (3)$$

in which m is the mass of the critical organ, c is the concentration in the critical organ, f_w is the fraction of that taken into the body by ingestion that arrives in the critical organ and I is the normal daily intake. Another useful value needed in establishing q that can be obtained by the spectrographic analysis when $Tr >> T_b$ is the fraction f_2 deposited in the critical organ of that in the total body as given by the equation:

$$f_2 = \frac{mc}{M} \qquad (4)$$

in which M is the mass of the element in the total body. Also by a spectrographic analysis of the feces it is possible to obtain approximate values of the fraction f_1 going from the GI tract to the blood by substituting in the equation:

$$f_1 = \frac{A - B}{A} \qquad (5)$$

in which A is the amount of the element taken into the body per day in the food and B is the amount of the element eliminated by way of the feces per day.

The survey program outlined above for determining the stable elements in the human body, in the average diet, and in the excretions, makes it possible in many cases to select the critical body organ and to find f_1 and f_2. However, T_b cannot be determined by this method unless f_w is obtained. The f_w is given by the equation:

$$f_w = f_1 f_2' \qquad (6)$$

in which f_2' is the fraction of that taken into the blood that is deposited in the critical organ. In most cases f_2' is unknown and sometimes a rather poor approximation is made by placing $f_2' = f_2$. However, in many cases f_2' and/or f_w are found directly from animal experiments. This practice of using animal data to obtain f_w may in some cases introduce serious errors and one solution is to make greater use of the tracer experiments as applied to terminal patients or other volunteers, and later examining the autopsied material. In any case, and regardless of the difficulties of obtaining human data, there is no completely satisfactory substitute. The stable element survey is especially attractive for this purpose because it makes full use of equilibrium exposure conditions of man. The limitations of this method, although considered to be minor, may be summarized as follows: (1) the stable element may not have the same chemical and physical form as the average radioisotope of the same element; (2) the concentrations may differ widely in the two cases and this in turn may influence the value of f_w and T_b; (3) some of the elements such as Pu^{239} do not appear in sufficient quantity in the normal environment. There are many other interesting developments in this stable element survey of human tissue which cannot be discussed here. For example, an element analysis of malignant tumors may furnish helpful leads to an understanding of the cause and/or a cure, and the absence or presence of large concentrations of certain elements in some of the body tissues may suggest a relationship to certain human diseases.

The emphasis placed on human experimentation in the discussion above may have made it appear that animal experiments are not sufficiently applicable to man to be worth while. Certainly this is not the case for, whereas human experiments must be done ultimately in large numbers it will be many generations before a sufficient quantity of such data for the 100 elements and for the various isotopes in the many chemical and physical forms can be accumulated in quantities of statistical significance. In the meantime we must rely in large measure on animal data but even here animal data are currently non-existent for some radioisotopes and only indirectly applicable to many others. In setting MPC and q values for continous exposure one would like to have data on animals that have been continuously exposed to fixed concentrations of the radioisotopes both in the drinking water and in air. By sacrificing these animals at various intervals and examining the tissue of the body organs, one can construct a continuous exposure curve such as the one shown in Fig. 4. In the case illustrated in Fig. 4, the effective half life of the radioisotope is five days and it can be seen that equilibrium is reached effectively in one month; since the concentration of the radionuclide in air or water was chosen correctly in this illustrative example, the curve saturates at an absorbed dose rate of 0.3 rem/wk in the critical organ. For the radioisotopes with a very long effective half life the correct MPC in air or water would be that for which the absorbed dose rate curve just reaches 0.3 rem/wk at 70 years, although in these cases equilibrium has not been reached, e.g., Pu^{239} has reached only 34% of equilibrium in the bone after 70 years. Such *continuous* exposure data are badly needed, but unfortunately it has been obtained in useable form only for Co^{60}. In all other cases values used in the internal dose handbooks[4,5] must be based on *single* exposure data such as those illustrated in Fig. 4. In calculating the continuous exposure MPC values from such a single ex-

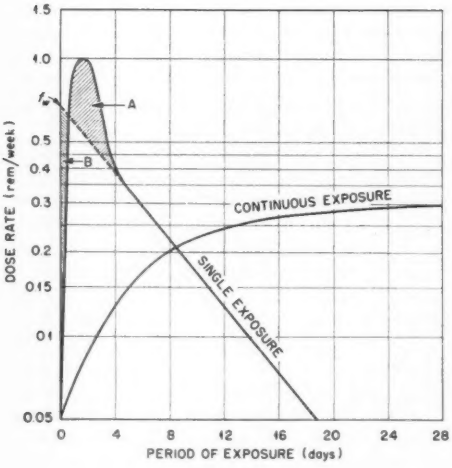


Fig. 4.

posure curve for the critical organ, the straight portion of the curve is extrapolated back to intercept the y-axis. This intercept is proportional to the fraction f_w of the radioactive material originally retained in the critical organ, if it had gone immediately to that organ. The slope of the straight portion of the curve gives the effective half life which is related to radioactive half life T_r and biological half life T_b by the equation:

$$T = \frac{T_b T_r}{T_b + T_r} \qquad (7)$$

It can be seen that this method of calculating the MPC values from the single exposure data is reliable only provided the curve is reasonably straight after the early rapid decay, and if the areas A and B in Fig. 4 are approximately equal. This method of analysis was checked[14] in the case of Co^{60} by taking two groups of animals, one given a single dose of Co^{60} by stomach tube, and the other given Co^{60} continuously in the drinking water. The animals from both groups were sacrificed at various intervals and the Co^{60} in the body organs measured. The continuous exposure curve calculated from the experimental single exposure data checked with the experimental continuous exposure data within a factor of two in every case and within 50% in most cases. Experiments are under way to check the common practice of calculating the maximum permissible continuous exposure values from single exposure data for other radioisotopes. However, it should be emphasized again that it is preferable to rely on continuous exposure data, and these data should be obtained as soon as possible so that the MPC and q values for continuous exposure as given in the handbooks refer directly to experimental data rather than calculations from single exposure data, and human data should be obtained to normalize the animal data curves until complete human information is available.

Data Needed

GENERAL TYPES OF EXPERIMENTAL DATA NEEDED TO ESTABLISH RELIABLE MAXIMUM PERMISSIBLE EXPOSURE VALUES: As explained above, human and animal data of a specific nature are needed for the establishment of MPC and q values for chronic exposure to the numerous radioisotopes in the various chemical forms. In additon, information of a general nature that applies to most of the radionuclides is needed. One such need is to determine the best values of RBE to use in these calculations. At present the common practice is to set RBE equal to 1 for x- and γ-radiation, β-particles and positrons, 10 for α-particles and protons, and 20 for oxygen, carbon, and nitrogen recoil ions. These assumptions were used by Snyder and Neufeld[15] in calculating the rem dose per neutron for neutrons of various energies incident on a large phantom of 30 cm depth. Some of their data—in both rem and rad units—are shown in Fig. 5 for incident neutrons of energies 5 kev and 10 Mev. In the case of 10 Mev neutrons at the maxima of the curves and at other depths in tissue the ratio of the absorbed dose in rem to the absorbed dose in rad units does not deviate much from ten and on this basis it is common practice when measuring the fast neutron absorbed dose in rad units to apply an RBE of ten. However, as a result of the refinements of fast neutron dosimetry by Hurst[16] and biological measurements by A. C. Upton,[17] W. Langham [18] and others, the RBE values for acute exposure, e.g., lethal effects, spleen and thymus weight loss, etc., seem to range between 1.2 and 2 rather than in the region of 10. It remains to check other biological changes, especially the chronic effects of

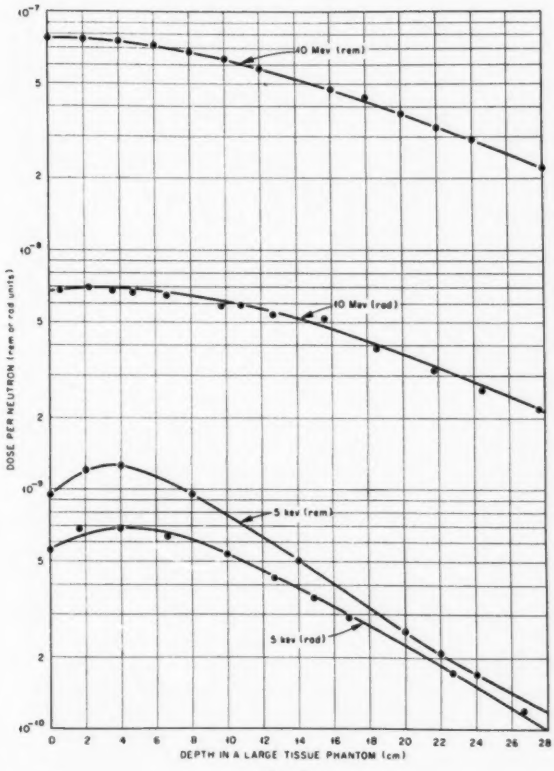


Fig. 5.

fast neutrons with the improved dosimetry and if the RBE for fast neutrons is between one and two for these effects, it is likely that the official RBE of fast neutrons and protons will be reduced. Also, as explained previously, RBE is believed to be a function of LET, and Snyder[19] is in the process of recalculating the maximum permissible flux values for neutrons, using the functional relationship between RBE and LET as given by Failla in the Handbooks.[4,6] The calculations are being made so that they can be modified easily—without recalculation—if this functional relationship is changed. Since Hurst[2] has given us a convenient means of measuring the average LET of fast neutrons, undoubtedly better data on RBE as a function of LET will soon be made available for refining all the present calculations of permissible exposure.

Another general term used in the calculation of MPC and q values is the nonuniform distribution factor N. As pointed out above, radium is not uniformly distributed in the bone and some other bone-seeking elements have even a more "spotty" or irregular distribution. As a consequence, in the calculations of MPC and q in the ICRP Handbook,[4] N was set equal to five for the particulate component of radioactive disintegration from all bone-seeking radionuclides except Ra^{226} and P^{32}. This value of N was chosen rather arbitrarily and it is to be hoped that it can be found experimentally for each of the bone-seeking radio-elements on the basis of microradiographic analysis of the various bone tissues. This factor N should be applied also to other body organs, especially to organs like the kidneys and lungs. Here the values of N should relate to the deviation from uniform distribution in the organ rather than the distribution of radium in the bone. It should be pointed out that when N was set equal to five for alpha from Pu^{239} and for beta from Sr^{90} by the Permissible Dose Conferences at Chalk River, Canada in 1949 and at Harriman, New York in 1953, its definition was not necessarily limited to "nonuniform distribution" of radionuclides, but rather it was a factor intended to express the relative hazard of various radionuclides on the basis of ergs/g of tissue. Since the principal factor in the explanation of why, for example, 1 erg/g from Pu^{239} produced five times the damage as 1 erg/g from Ra^{226} and its daughters deposited in the bone was "the relative unevenness of deposition," this terminology for N has evolved. Actually N should be the product of a number of factors which are considered to express the increased damage per erg/g from the radionuclide in comparison with the damage per erg/g from a reference radionuclide. The factors in addition to non-uniform distribution include essentialness of certain tissue, radiosensitivi-

ty, etc.; in other words, Pu^{239} may be more harmful than Ra^{226} plus its daughters not only because of more spotty distribution, but also because it localizes in portions of the bone that are more essential in the production of blood cells and the proper conditioning of other body functions and it may concentrate more in rapidly dividing cells that require less radiation to interfere with their natural function. Similarly other radioisotopes may localize in small volumes of tissue where they interfere with enzyme action or damage nerve centers which in turn limit the function of many other cells or of entire organs. Some radioisotopes may concentrate in the nucleus of the cells where they are most effective in producing both germ cell and somatic mutation.

The above discussion suggests that there should be an average radiosensitivity factor applied to each body organ. In most cases it is set equal to unity but it is 0.5 for the thyroid and the epidermal layer of the body, 0.2 for the skin of the hands, forearms, feet, ankles, head and neck for any type of radiation, and 0.2 for the epidermal layer of the entire body if the radiation is of low penetrating power such that the half value layer in tissue is less than 1 mm (see Fig. 1). However, this radiosensitivity factor as well as the "essentialness to proper body function" factor have influenced the choice of the critical body organ on which the MPC and q values are based in several cases. For example, although the concentration of some of the radioactive metals is found to be greatest in the erythrocytes, the liver is used as the critical tissue rather than the blood because it is considered to be less capable of tolerating radiation damage. The same argument was originally given with respect to the GI tract. However, in recent publications it is assumed that there is no reason to permit more radiation exposure to the GI tract than to the bone, liver or other body tissue and as a consequence the ICRP Handbook[4] lists the GI tract as the critical organ since almost without exception it receives a greater absorbed dose than other body tissue. However, since the exposure to the GI tract stops almost completely a few days after intake of radioactively contaminated air or water is discontinued, MCP and q values are listed also for other critical body organs. In fact, the significant q value is not that based on the GI tract but on the other critical organs listed in Table 8 of the ICRP Handbook.[4] This can best be understood by examining a few examples from this Handbook:

TABLE I.
RANDOM VALUES SELECTED FROM ICRP HANDBOOK[4]

Z	Radio-isotope	Critical Organ	Maximum Perm. Body Burden, q (μc)	Maximum Perm. Concentration in water (μc/cc)	Maximum Perm. Concentration in air (μc/cc)
62	Sm^{151}	Bone	90	5×10^{-2}	3×10^{-9}
		GI	$(14, 3 \times 10^{4})$	8×10^{-3}	10^{-6}
45	Rh^{105}	Kidneys	9	0.4	2×10^{-6}
		GI	(0.02,0.9)	10^{-3}	2×10^{-7}

In the case of Sm^{151} the critical body organ is the GI tract for ingestion but the bone for inhalation and for Rh^{105} the GI tract is the critical organ in both cases. It should be pointed out that the choice of the GI tract is based actually on the lower large intestine where it is assumed the GI contents remain 18/31 of the total time in the GI tract, i.e., in this discussion and in the Handbooks "GI tract" refers to the "lower large intestine." In the case of inhalation of Sm^{151} the bone is the critical organ as a result of the fact that 62 per cent of the Sm^{151} which is inhaled is swallowed and the effective halflife, T, for Sm^{151} in the bone is very large. The examples in Table 1 apply only to the case of continuous exposure over a lifetime of 70 years, during which time Sm^{151} with $T = 3.9 \times 10^4$ days in the bone, reaches only 36% of equilibrium in the bone but reaches 100% equilibrium in the GI tract in a few days. The Rh^{105} with a value of $T = 1.5$ days in the kidneys reaches equilibrium in the kidneys in about a week and in the GI tract in a few days. The values in parentheses in column four are not true values of body burden, e.g., the first value in parentheses is the amount that would be in the total body if water having an MPC value based on the GI tract as the critical tissue were used over an extended period of time, and the second value is the amount that would be in the total body if the air having an MPC value based on the GI tract as the critical tissue were inhaled for a long time. During such periods of exposure the lower large intestine would receive an average absorbed dose rate of 0.3 rem/wk but if con-

sumption of the contaminated water or air were discontinued the principal absorbed dose would be to the bone in the case of Sm^{151} and to the kidneys in the case of Rh^{105}. The big question here seems to be the wisdom of using the GI tract—or more specifically the lower large intestine—as the critical organ. It is of interest perhaps to note that of the 355 MPC values listed in the ICRP Handbook[4] 71% of the MPC values for ingestion and 41% of the MPC values for inhalation refer to the GI tract as the critical organ and 11% of the MPC values for ingestion and 28% of the MPC values for inhalation refer to bone as the critical organ. Therefore, because of the importance of the GI tract and the bone, radiation damage studies of these organs should be accelerated. Although single exposure MPC values are not given in the handbooks, unofficial tables of calculated[20] values have been published and it is of interest to note that the lung is the critical organ for 83% of the single exposure inhalation values when the calculations are based on the amount of the radionuclide inhaled in a 24-hour period that would result in an exposure of 0.3 x 52 = 15.7 rem during the ensuing year. The critical organ was the lung for about half the radionuclides and the GI tract for most of the other radionuclides when the single exposure MPC value was based on the amount of the radionuclide inhaled in a 24-hour period that would result in an exposure of 0.3 rem during the ensuing week. Various criteria of permissible single exposure MPC values are being studied and it is hoped that suitable values can be officially agreed upon in a few years.

Another problem of considerable interest to the Health Physicist who is selecting MPC and q values is the translocation of elements, especially the daughter products of parent elements. As explained above, in the case of the Ra^{226} and Ra^{228} chains it is assumed that all the daughter elements that are produced in the bone continue at the site of the parent with the exception of the noble gas Rn^{222} in which case it is assumed 45%—together with the daughters of Rn^{222}—escapes into the blood and is exhaled. Perhaps there is considerable translocation of the daughter elements in many of the chains and it would be of interest to make a careful study of this problem.

It is known from experiments of Friedell[21] that in some cases there is a synergestic effect; that is, if x μc of isotope X and y μc of isotope Y each produce the same damage, $x/2 + y/2$ μc do not necessarily produce the same damage. In some cases the damage from X and Y when given concurrently is greater and in other cases it is less than the damage of either given separately. Experiments seem to indicate for example that if isotope X goes to the bone and Y to the spleen, damage from $x/2$ and $y/2$ is likely to be greater than damage from x or y alone. This may be a result of the ability of the spleen to take over the production of formed elements in the blood if the need arises and when both spleen and bone marrow are damaged simultaneously, neither can serve as a crutch for the other. Synergism is a problem when considering the hazard from a radioisotope like Po^{210} which deposits both in the spleen and the bone or from parent and daughter radioisotopes like $Pb^{210} + Bi^{210} + Po^{210}$ in which the 22-year Pb^{210} is localized in the bone and part of the five day Bi^{210} and 140 day Po^{210} may be translocated to the spleen and other related organs. On the other side of the argument it should be recognized that in some cases exposure to two separate organs may produce independent and unrelated damage. For example, insoluble uranium deposited in the lungs may produce damage that only slightly limits the damage that would be permitted from external β-radiation of the hands or that has little if any influence on the maximum permissible body burden, q, that is permitted for S^{35} which delivers most of its absorbed dose to the skin.

It is beyond the scope of this discussion to outline the need for genetic data to serve as a basis for acceptable MPC and q values. It should be pointed out that there are many types of genetic damage besides lethal mutations; that from one point of view recessive mutations are just as real and harmful as dominant mutations; and that there are many first generation effects[22] that may be of great concern to exposed individuals who have not passed the childbearing age. Most of the early genetic data available were based on drosophila and organisms far removed in the scale of evolution from man but recent experiments of

Dr. Russell[23] with mice indicate that the mutation rate per rad is 100 times higher for mice than for the lower organisms. Genetic data are badly needed for establishing the permissible accumulated absorbed dose not only for occupational exposure but also for exposure permitted to the population at large. Rather arbitrarily 10% of the MPC values for occupational exposure are being used as permissible levels for disposal of radioactive contaminants in the air and water of the general environment. As soon as possible we should know the genetic effects of both occupational and non-occupational exposure to radiation and the consequence of this exposure with respect to other human damage such as increased tumor incidence, effect on fertility, shortening of life span, etc. Some of the indirect ecological effects of radiation are of equal importance to the well-being of the human race. We need to know what concentration of the various radioisotopes can be placed in our rivers before the factors of selective absorption in the plankton, algae and other fish food will result in concentrations in the fish that could be harmful to fish and to those who use them for food. Also we need to know what concentrations can collect on our soil before factors of selective retention in certain types of bacteria, fungi and arthropods will upset the food web of the forest floor or of the grain fields such that decaying vegetation will not be returned to the plant roots in a usable form and as a result forests and grain fields are damaged. There is no end to the amount of such data that are needed for completely reliable MPC values but this should not discourage present investigations or delay the start of other programs directed toward obtaining this information.

Administrative Problems

As would be expected there are many problems of an administrative nature in applying maximum permissible exposure values and a few of them will be discussed. One problem is that of exposure records. Most laboratories are convinced of the need of maintaining personnel exposure records of some kind but in many cases the records are incomplete and inaccurate and in most cases the number of records is staggering so that the space requirements for storing these records is a problem. The records are often incomplete because they fail to record certain types of absorbed doses such as that from neutrons and β-rays, and in only a few cases is any accounting made of medical exposures. Where medical exposures are recorded there is difficulty in knowing which ones to list and which to ignore. Most of the medical exposures are of a localized nature and there is no completely reasonable way of adding them in with other data where most of the exposures are total body. Handbook 59[6] is very generous on the question of accounting for medical exposures. It states in short that medical exposures from x-rays need not be considered. An exception is made in the case of fluoroscopic examinations of the internal organs of the trunk of the body repeated within one month if the absorbed dose to the whole body exceeds 25 r or the local exposure to the hands, forearms, feet and ankles exceeds 125 r, and provided there is an accidental or emergency exposure of 25 r to the total body or local exposure of 125 r to the hands, forearms, feet and ankles that has occurred within three months. Since these accidental or emergency exposures are permitted to occur only once in a lifetime and are avoided at all times, it is unlikely that the rule in Handbook 59 would ever make it mandatory that an accounting of a medical exposure be made or that it would affect the radiation tolerance status of a person. However, many health physicists do not share this point of view and it is the opinion of many of them that a fluoroscopic examination involving an exposure of 10 or 50 r should be recorded on a person's exposure record regardless of whether or not the person happens to be the one in 10,000 that has received an accidental or emergency exposure within three months. There may be some difficulty in obtaining good estimates on the absorbed dose received in a fluoroscopic examination or other type of medical exposure to a large amount of radiation but we are living in an atomic age, we are trying to keep personnel exposure records that are useful to the individual and the employer, and it would reduce the problem to an absurdity to keep occupational exposure records of an individual which add up to 10 to 50 rad in 10 years but to ignore three fluoroscopic examinations which con-

tribute 100 r to the person's exposure during this period. Some laboratories keep radiation exposure records as property of the laboratory which are available for inspection by any health physicist or medical man but assume these records might be misunderstood or misused if given to the laboratory employee. Other laboratories furnish the exposure records regularly or upon request to the individuals. Although some laboratories do not automatically transfer exposure records to another laboratory when a person transfers, all of them will furnish these records to the other health physics or medical department upon request. Many problems will be solved when the masses of people have sufficient knowledge of the meaning of radiation exposure readings that it is practical for each to be required to carry with him a radiation exposure record along with his inoculation card and social security number.

Handbook 59[6] permits an accidental or emergency exposure of 25 rads to the total body or 125 rads to the hands, forearms, feet and ankles once in a lifetime. At first thought one might consider that this is a big concession. However, this is intended to take care only of the accident or extreme emergency and once a person has, for one cause or another, used up this "premium" exposure, he has no more "credit" for large exposure and his work for the rest of his life must be so modified and regulated that he will never again receive such an exposure. Handbook 59 states, "Accordingly, it is generally desirable to institute compensatory measures in such cases. This is particularly true when the conditions of occupational exposure are such that the possibility of recurrence of technical overexposure cannot be excluded." A "technical overexposure" is defined as an absorbed dose greater than the permissible weekly exposure ($>$ 0.3 rem/wk). It might be a great inconvenience to a man to modify his life work on account of such an accidental or emergency exposure so that he could exclude the possibility of a technical overexposure; therefore, it would be very much to the advantage of the employee and the employer to make considerable effort to avoid accidental or emergency exposures. A similar but only temporary penalty applies to a person who exceeds the 0.3 rem basic absorbed dose in one week and who elects to receive up to 0.9 in a week. In this case he must be penalized 25% of the permissible dose during a 13-week period. Therefore a person engaged in a hot operation may find it convenient to receive 0.9 rem/wk for a three-week period but during the remaining 10 weeks he could receive only an additional 0.3 rem. This 25% penalty has proved very effective in many hot laboratories in encouraging supervisors to plan their programs in order not to restrict their men to 25% less hot work.

Although Handbook 59 permits doubling the basic exposure rate, i.e., from 0.3 to 0.6 rem/wk, after the age of 45, perhaps very few if any laboratories will take advantage of this feature because it would seriously complicate the keeping of records. However, it does permit greater flexibility in the radiation exposure regulations so that when very hot jobs must be done in an emergency the employer will be encouraged to use older men for the job who would be less likely to be affected by genetic considerations and who would have fewer years to suffer if they should receive some increased probability of radiation damage. This feature loses some of its attractiveness from the viewpoint of the health physicist because in most operations it is the older men who have accumulated the largest absorbed doses of radiation and this regulation would be tantamount to telling these older men "Well boys you have done a good job of accumulating more exposure than the rest of the fellows and as a special reward on this 20th anniversary we will permit you hereafter to double your absorbed dose rate." Fortunately, administrative difficulties will spare us from such an embarrassing announcement.

Blood counts are not required by Handbook 59 for it is considered that they would furnish no useful monitoring data in the exposure range that is considered to be permissible. The ICRP Handbook[4] states that "routine blood counts are optional in the case of workers who receive doses between $\frac{1}{3}$ and $\frac{2}{3}$ of the permissible doses; and routine blood counts are desirable in the case of workers who receive doses exceeding $\frac{2}{3}$ of the permissible doses." Although there is no compulsion in this rule it does point out a desirability of keeping

blood count records for groups of people who are accumulating large exposures. The accumulation of good statistics on humans exposed in this absorbed dose range would be very useful and might give an indication at what level of exposure persons should receive blood counts. Data, not only on the usual counts, i.e., lymphocyte count, erythrocyte count, etc., would be desirable, but also other research data such as the polynucleated cell count would be enlightening.

The policy of female exposure differs among the laboratories. Many of them do not permit women that have not passed the child-bearing age to engage in hot operations or even to work on areas where large exposures are likely. Handbook 59 adds a word of caution on this in stating "Women of reproductive age shall not be subjected to planned emergency exposure." It is the early period of pregnancy that is most serious and since it is impossible in general to tell which female might be pregnant during this critical period, Russell[22] has suggested that large medical exposures to women be restricted to the relatively safe interval of the two weeks following the beginning of the menstrual period.

One of the most difficult administrative problems at present is that of maintaining the average exposure rate well below the maximum permissible exposure rate in certain hot operations in order that the lifetime absorbed dose will not exceed safe limits. No maximum permissible lifetime absorbed dose has been given in any of the handbooks but as explained previously it is not intended that a person should average the maximum permissible absorbed dose rate over a lifetime. The present writer has suggested 150 rem, and work in our laboratory (ORNL) is so planned that it is not expected anyone will exceed this value in a lifetime at his present rate of exposure—barring, of course, serious accidents. However, in some cases it is costly to operate with average exposure rates well below the maximum permissible values, and unless the official handbooks list a lifetime absorbed dose within the next few years, many people, especially those in certain production operations, may be on the way toward accumulating an excessive lifetime exposure, and many plants will be constructed with operations established in such a way that it will be difficult to reduce to a lifetime absorbed dose of not more than 150 rem.

References

1. NEUFELD, J.: Electron Capture and Loss by Moving Ions in Dense Media. *Phys. Rev.*, 96:6, 1470 (December) 1954.

2. HURST, G. S., RITCHIE, R. H., MILLS, W. A., HARTER, J. A., and HENSLEY, P. N.: ORNL-1671 (classified).

HURST G. S., MILLS, W. A., CONTE, F. O., and UPTON, A. C.: Fast Neutron Dosimetry in the ORNL 86-inch Cyclotron. Will be published in *Radiation Research Journal*, 1955.

3. MORGAN, K. Z.: Relative Biological Effectiveness. Fifth Conference on Radiation Cataracts, March 26, 1954, National Research Council, Washington, D. C.

4. Recommendations of the International Commission on Radiological Protection. British Inst. of Radiology, 32 Welbeck St., London W 1, Eng.

5. Handbook-52 of the NBS. Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. For sale by Superintendent of Documents, Washington 25, D.C.

6. Handbook 59 of the NBS. Permissible Dose from External Sources of Ionizing Radiation. For sale by Superintendent of Documents, Washington 25, D.C.

7. International Recommendations for X-Ray and Radium Protection. *Radiology*, 23:682-685 (1934); 30:511-515 (1938).

8. National Bureau of Standards Handbook H 20, X-ray Protection, 1936; H23, Radium Protection, 1938; Superintendent of Documents, Washington 25, D.C.

9. HENSHAW, P. S., and HAWKINS, O. W.: Incidence of Leukemia in Physicians. *J. Nat. Cancer Inst.*, 4:4, 339, 1944.

MARCH, H. C.: Leukemia in Radiologists in a 20-Year Period. *Radiology*, 43:275, 1944, and *Am. J. Med. Sc.*, 220-282, 1950.

PELLER, S., and PICK, P.: Leukemia and Other Malignancies in Physicians. *Am. J. Med. Sc.*, 154, 224, 1952.

10. EVANS, R. D.: Radium Poisoning: A Review of Present Knowledge. *Am. J. Pub. Health*, 23, 1017-23, (1933).

EVANS, R. D.: Radium Poisoning: II Quantitative Determination of Radium Content and Radium Elimination Rate of Living Persons. *Am. J. Roentgenol. & Rad. Therapy*, 37, 368-378, (1937).

EVANS, R. D.: Protection of Radium Dial Workers and Radiologists from Injury by Radium. *J. Indust. Hyg. & Toxicol.*, 25, 253-269, (1943).

LOONEY, W. B.: Chronic Radium Toxicity—A Progress Report on Clinical Studies on 24 Patients. Argonne National Laboratory. ANL-4666, (1951).

LOONEY, W. B., HASTERLIK, R. J., BRUES, A. M., and SKIRMONT, E.: Clinical Investigation of Chronic Effects of Radium Salts Administered Therapeutically (1915-1931). To be published in *Am. J. Roentgenol. Rad. Therapy & Nuclear Med.*, June, 1955.

NORRIS, W. P., SPECKMAN, T. W., and GUSTAFSON: Studies of the Metabolism of Radium in Man. *Am. J. Roentgenol. Rad. Therapy & Nuclear Med.*, 73, 785-802, (1955).

SILBERSTEIN, H. E.: Radium Poisoning: Survey of Literature Dealing with Toxicity and Metabolism of Absorbed Radium. AEC Document 2122, (1945).

Report of the Second Annual Conference on Plutonium, Radium, and Mesothorium at Salt Lake City, Utah (June, 1954). Compiled and edited by C. N. Stover, Jr., Radiobiology Laboratory, University of Utah, College of Medicine, Salt Lake City, Utah.

11. BURNETT, T. H. J.: Comparative Dosage Study Ra vs. $MsTh_1$. ORNL-CF-50-12-118.

12. BRUES, A. M., MARINELLI, L. D., and HASTERLIK,

R. J.: A Progress Report of Clinical Studies on 24 Patients. ANL-4666, July, 1951.

13. TIPTON, I. H., and STEINER, R. L., *et al*: Spectrographic Analysis of the Tissues from Autopsies of 24 Instantaneous Deaths. ORNL-54-12-66, December (1954).

14. COOK, MARY JANE, BARKOW, A. G., and MORGAN, K. Z.: An Experiment Designed to Test the Validity of the Current Practice of Using Single Exposure Data to Calculate Maximum Permissible Concentration in Water for Continuous Exposure to Radioisotopes. To be published in *Am. J. Roentgenol.*, 1955.

15. SNYDER, W. S., and NEUFELD, J.: Depth Dose Curves. ORNL-1872. To be published in the *Brit. J. Radiology*, 1955.

16. HURST, G. S., MILLS, W. A., CONTE, F. P., and UPTON, A. C.: Principles and Techniques of Mixed Radiation Dosimetry Application to Acute Lethality Studies of Mice with the Cyclotron. To be published in *Radiation Res. J.*, 1955.

17. UPTON, A. C., CONTE, F. P., HURST, G. S., and MILLS, W. A.: The Relative Biological Effectiveness of Fast Neutrons, X-rays, and Gamma Rays for Acute Lethality in Mice. To be published in *Radiation Res. J.*, 1955.

18. LANGHAM, W. H., and STORER, J.: Quantitative Biological Methods for Studying Radiation Effects in Mammals. Paper presented at the Radiation Research Society Meeting in New York, May 18, 1955.

19. SNYDER, W. S.: At present Snyder is repeating the Monte Carlo calculations, using the ORNL digital computer. The results will be published in the NBS Handbook on neutrons early in 1956.

20. MORGAN, K. Z., and FORD, M. R.: Developments in Internal Dose Determinations. *Nucl.*, 12:6, 32-39, (June) 1954.

21. FRIEDELL, HYMER, L., and CHRISTIE, J. H.: The Synergistic Effect of Phosphorus-32 and Colloidal Gold-198 on Survival in Male Albino Rats. NYO-1609, July 6, 1950.

22. RUSSELL, L. B., and RUSSELL, W. L.: Radiation Hazards to the Embryo and Fetus. *Radiology*, 58:3, 369-76, (March) 1952.

23. RUSSELL, W. L.: X-ray Induced Mutations in Mice. *Coldspring Harbor Symp., Quant. Biology*, 16, 327-336, 1951.

Honorary Memberships

THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION has recently created an Honorary Membership within the ASSOCIATION. The Board of Directors may elect as Honorary Members such persons as are particularly distinguished in the general field of industrial hygiene or in a closely related scientific field. At the meeting of the Board of Directors in Pittsburgh on November 16, three persons were elected to Honorary Membership for long and distinguished service in the field of industrial hygiene: DR. ALICE HAMILTON, Hadlyne, Connecticut; DR. LUDWIG TELEKY, New York, New York; DR. ROYD R. SAYERS, Washington, D. C.

Special Fellowships

THE Atomic Energy Commission is sponsoring fellowships in industrial hygiene at Harvard University and the University of Pittsburgh. Applicants must have a bachelor's degree with a major in physics, chemistry, or engineering and must be acceptable for graduate work at the university to which they are assigned. Academic training beyond the bachelor's degree, or industrial experience, is desirable. Fellows must be under 35 years of age and must be citizens of the United States. The fellowship is for the academic year beginning in the fall of 1956. When possible, applicants will be assigned to the school of their choice. The basic stipend for the academic year is $1,600. An additional $350 is allowed for a wife and $350 for each dependent child. Normal tuition and fees required by the university are paid by the fellowship. Fellows with one or more years graduate work or industrial experience may qualify for an additional $200 in the basic stipend. Application forms and further information may be obtained from the Fellowship Office, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tennessee. Completed applications must be returned to the Oak Ridge Institute of Nuclear Studies by March 1. Appointments will be made about March 15.

Skin Testing of Industrial Compounds

DEVELOPMENT OF POLYVALENT SENSITIVITY

E. VON HAAM, M.D., Department of Pathology
Ohio State University, Columbus
F. S. MALLETTE, Ph.D., Medical Department
Firestone Tire and Rubber Company, Akron, Ohio

ALTHOUGH patch testing procedures were originally developed to discover certain specific allergies in clinical patients, they have been more and more frequently adopted by industrial medicine for the determination of skin irritating and sensitizing properties of chemical agents and materials.[1] Almost innumerable situations exist today in which it is necessary to estimate as rapidly as possible the effect certain materials have when they make contact with the skins of a large number of persons. For the estimation of a prohibitive degree of irritancy two tests have proved successful: the dressing test and the patch test.[2] The latter was devised by Jadassohn almost fifty years ago for the demonstration of the cause of contact dermatitis. In the United States the patch test has been used more and more frequently since the United States Public Health Service called attention to the prevalence of occupational dermatitis.[3] First employed as a means of determining the causative chemical irritant of contact dermatitis, it has now become a means of determining the possible skin irritating or sensitizing properties of new chemical compounds before they are placed before the public. This is called the "prophetic" patch test of Schwartz and Peck.[4]

In the past seven years we have used the prophetic patch test on 292 compounds used in the rubber and plastics industries. Some of our results were published in two previous reports concerning the skin effects of certain accelerators, activators, antioxidants and plasticizers.[5,6] Recently Sunderman and Haag[7] took exception to two of our observations and published results which contradict our own findings. The substances in question were two plasticizers, namely, Paraplex G-25 and G-40, which were considered by us as severe irritants and moderate sensitizers according to tests performed in 1948 and published in 1952. Checking our results with a similar technique and concentrations employed in our laboratory Sunderman and Haag found both substances to be neither irritating nor sensitizing. This obvious discrepancy posed a puzzling problem for which an explanation had to be found. The studies presented in this paper were therefore undertaken for the purpose of discovering, if possible, the cause for these divergent results.

Presented at the Sixteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Buffalo, New York, April 28, 1955.

Technique of the Patch Test

IN ORDER to avoid any misunderstanding it was felt that the technique of the patch test as now used in our laboratory should be described in more detail than was done in previous communications. The technique is similar to that published by Schwartz in "Industrial Hygiene and Toxicology," edited by Patty, employing an occlusive dressing of adhesive tape measuring 2 in. square, a cellophane insulation 1 in. square and an absorbent cotton center ½ in. square.[3] Solid substances are attached to the cotton by means of cold cream, while liquid substances are adsorbed to the cotton. Substances suspected of highly irritating qualities are always first tested on animals. Groups of three albino rabbits are used for each test and the substance is fixed to the shaven skin of the back. Only those levels not irritating to the skins of animals are used for testing on humans. Proper dilution of the material to be tested was pre-

viously done with propylene glycol but in the past five years with cold cream. Concentration levels of 1%, 5%, 25% and 100% are used for the skin testing. Concentration levels which proved definitely non-irritating are used for testing of sensitivity two weeks after the irritancy test has been performed. Test subjects are human volunteers chosen from the students of the College of Medicine at Ohio State University and employees of the College of Medicine and some of their close relatives. The subjects are chosen on a volunteer basis and remunerated for their services. They are of both sexes, belonging to the white race and ranging in age from 20 to 40. Until recently no special care was taken in choosing individuals for the tests and no attempt was made to elicit a history of any previous skin disorder or allergy. The patch is applied to the skin of the back and frequently several patches are applied simultaneously containing the material of one or more test substances in varying concentrations. Unless the subject complains of painful irritation the test is left in place for 48 hours with the subject refraining from taking a bath during this period. It is then removed and the reaction is read immediately and again from three to seven days later. Immediate and delayed reactions are classified according to accepted standards as follows:

No reaction or slight discoloration of the skin due to the material used..negative
Erythema usually having the contours of the cotton center or of the solid material .....1+
Raised erythema with palpable induration .....2+
Vesiculation .....3+
Maceration of the skin with superficial necrosis and the formation of eschars .....4+

A control for the adhesive tape, for the diluent and for the vehicle of the compound if the latter is known are used separately in each case. Groups of 15 to 20 volunteers are used for each patch test. For the determination of the sensitizing properties of the compound in question the patch test is repeated with a non-irritating concentration of the material two weeks later in similar fashion and readings are made 48 hours after application of the test for immediate reactions and three to seven days later for delayed reactions. From these tests indices of irritancy (I.I.) and sensitivity (I.S.) are computed by multiplying the degrees of reaction with the number of individuals showing them and dividing by the number of persons used in the test. If, for example, we would obtain in a group of 20 individuals three 3+ reactions, four 2+ reactions, four 1+ reactions and nine negative reactions, the index of irritancy would be:

$$\text{I. I.} = \frac{(3x3)+(4x2)+(4x1)+(9x0)}{20} = 1.05$$

Any substance producing an irritancy index or sensitizing index of 0 to 0.49 is considered as non-irritating or sensitizing; substances with indices from 0.5 to 0.99 are considered as slightly irritating or sensitizing; substances with indices from 1 to 1.49 are considered as moderately irritating or sensitizing; and substances with indices above 1.5 are considered as severely irritating or sensitizing. Thus in the example quoted above the tested compound would be classified as moderately irritating. If one or two very severe reactions are observed without any instance of moderate or slight reaction, the test is repeated on another group. It has been our experience that sensitivity tests tend to produce an equal or higher number of delayed reactions than immediate reactions, and if the number of immediate reactions outnumbers by far the number of delayed reactions the dose level of the material is considered too irritating for proper evaluation of sensitivity.

Analysis of Previous Results

USING these criteria we felt that we had worked out a pretty useful standard procedure of measuring the skin irritancy and skin sensitivity of various materials and we felt quite confident of our results until Sunderman and Haag's publication suggested to us the necessity for reinvestigation of our method. First, of course, we checked our previous results on large groups of test subjects using the old material which had been saved and new material obtained from the factory. We could fully confirm the results of Sunderman and Haag that neither of the substances in question can be considered irritating or sensitizing. We then analyzed our old records of the skin

tests performed in 1948. The only discrepancy between our previous tests and the reëxamination of the material was found in the type of subjects on whom the tests were performed. In 1948 the group contained many individuals who probably for financial reasons had volunteered at every offered opportunity and had been used by us repeatedly at a time when a large number of materials were studied. Our repeat tests were performed by coincidence principally on a group of medical students, freshmen or sophomores, who had just returned from summer vacation and most of whom had never been used as a test subject before. This discrepancy suggested to us the possibility that perhaps certain individuals may develop an increased irritability of the skin without the strict specificity of allergic sensitization and that this nonspecific or polyvalent sensitivity may be responsible for a certain amount of reactions. In re-analyzing a group of 100 test subjects we found that half of them had been tested more than 20 times, three of them more than 50 times, during a period of years. On questioning, some of them stated voluntarily that they felt that they became more sensitive to skin tests than they had been at the beginning of these tests. In order to investigate more thoroughly this problem of changing skin irritability we devised three experiments, which we shall report briefly.

Experiment A: In the first experiment six non-sensitizing compounds, three of them classified as non-irritating, two as slightly irritating and one as moderately irritating, were applied to 10 individuals who had had at least 20 patch tests previously but who had not been tested with any of the six substances or substances chemically related to them. At the same time the compounds were applied to 10 subjects who had never had a patch test before.

The results given in Table I show a marked difference in the skin reactions between the two groups of subjects. All three of the non-irritating compounds gave negative reactions in both groups. The two slightly irritating compounds proved negative in new subjects and slightly or moderately irritating for the old reactors. The moderately irritating compound was only slightly irritating to new subjects and severely irritating to old reactors. We feel that this experiment lends strong support to our suspicion that repeated skin tests do indeed increase the irritability of the skin of certain individuals.

TABLE I.
EXPERIMENT A

Compound Prot. No.	Previous Tests		Old Reactors		New Subjects	
	I.I.	Classif.	I.I.	Classif.	I.I.	Classif.
17	0.7	Slight	1.4	Moderate	0.3	Negative
306	0.2	Negative	0.4	Negative	0.1	Negative
562	1.3	Moderate	1.9	Severe	0.6	Slight
158	0.1	Negative	0.2	Negative	0.1	Negative
480	0.6	Slight	0.6	Slight	0.2	Negative
581	0	Negative	0	Negative	0	Negative

Experiment B: The second experiment represents an attempt to produce this increase in nonspecific skin irritability in a group of new subjects by performing a large number of patch tests with chemically unrelated and non-sensitizing compounds in a relatively short period of time. For this purpose 10 new subjects who had never been tested before were patch tested with 24 compounds over a period of four weeks. The compounds chosen had all been tested before and consisted of 12 substances considered non-irritating and non-sensitizing and six substances considered moderately irritating and non-sensitizing. They were applied in such fashion that the irritating compounds and the non-irritating compounds interchanged. The same compounds were also applied to 10 old reactors who had never before been tested with those specific compounds. The results of this experiment are presented in Fig. 1.

All 12 non-irritating compounds proved

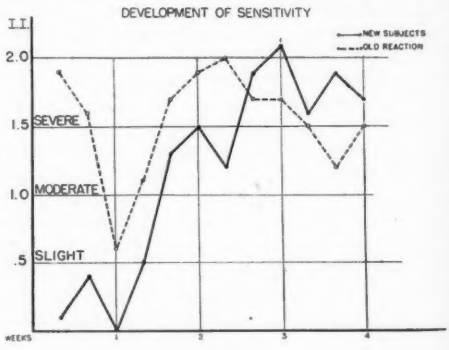


Fig. 1.
The development of increased skin irritability.

TABLE II.
EXPERIMENT B

Test Subjects	Development of Irritation (I.I.)			
	1st Week	2nd Week	3rd Week	4th Week
Old reactors	0.7	0.28	1.0	1.28
New subjects	0.15	0.13	0.6	1.55

non-irritating when re-tested against the old reactors and the group of new subjects and for this reason are not recorded in the chart. The 12 slightly or moderately irritating compounds, however, produced entirely different reactions in the new subjects of the experiment. While at first the reactions were much less severe than should have been anticipated from our previous tests of those compounds, the degree of the reactions increased rapidly and during the third and fourth weeks equaled or even surpassed the severity of the skin reactions obtained with the same compounds in the group of old reactors. Average irritation indices computed for six compounds tested each week showed the greatest difference between the old reactors and the new subjects during the first week and a markedly less difference in the third and fourth weeks.

We felt that this experiment proved that it was possible by repeated skin tests with unrelated and non-sensitizing compounds to increase the irritability of the skin in test subjects. Five of the 10 individuals developed this increased irritability rather early and to a pronounced degree, four developed it late and to a much less degree. Only one individual did not show any increased irritability after this battery of patch tests. It was important to us to note that the non-irritating compounds remained non-irritating regardless of the changed irritability of the skin.

Experiment C: In the third experiment we tried to demonstrate again to our satisfaction that the condition suggested in Experiment A held true for the individuals in whom we had just increased the skin irritability experimentally. For this purpose a group of 10 old reactors and the 10 subjects employed in Experiment B were tested and compared with 20 new subjects who had never been tested before, using 12 compounds chosen from our stock of 292 compounds previously tested. All 12 compounds chosen for this experiment were non-sensitizing, four were non-irritating, four slightly irritating, three moderately irritating and one severely irritating in previous tests. Results are tabulated in Tables III and IV.

Table III shows that the reactions elicited among the old reactors and those whose skin irritability had been recently increased were about the same, and more severe than the skin tests obtained previously with those compounds on a mixed group of subjects In contrast to this, the reactions obtained by those 12 compounds in the new group of persons who had never been tested before were so much less severe that only two of the 12 compounds could be considered slightly irritating and one moderately irritating. The number of the various types of reactions obtained with these compounds in the three different groups of individuals and the average indices of irritation are computed in Table IV and demonstrate again the outstanding difference in the irritability of the skin among subjects previously subjected to patch tests and new subjects. (See also Fig. 2.)

TABLE III.
EXPERIMENT C

Compound	Previous Tests		Old Reactors		Trained Reactors		New Subjects	
Prot. No.	I.I.	Classif.	I.I.	Classif.	I.I.	Classif.	I.I.	Classif.
563	0.8	Slight	2.0	Severe	1.9	Severe	0.05	Negative
549	1.4	Moderate	3.3	Severe	3.1	Severe	0.85	Slight
528	1.5	Severe	2.1	Severe	1.7	Severe	0.15	Negative
4	0.1	Negative	0.6	Slight	0.9	Slight	0	Negative
69	0.3	Negative	0.4	Negative	0.3	Negative	0	Negative
70	0.3	Negative	0.1	Negative	0.2	Negative	0	Negative
494	0.75	Slight	1.8	Severe	2.1	Severe	0.05	Negative
481	1.0	Moderate	1.5	Severe	2.1	Severe	0.15	Negative
466	.73	Slight	2.1	Severe	2.2	Severe	0.5	Slight
414	1.4	Moderate	1.4	Moderate	1.0	Moderate	1.0	Moderate
339	0.6	Slight	0.5	Slight	0.3	Negative	0.15	Negative
Control	0	Negative	0	Negative	0.05	Negative	0	Negative

Fig. 2.
Two examples from test subjects in Experiment C: Left: Skin reaction in individual never skin-tested previously. Right: Skin reaction in individual of Experiment B showing increased irritability of skin.

Animal Experiment

WE FINALLY tried to see if similar results could also be obtained in animal experiments. For this purpose three rabbits were tested with 18 different compounds over a period of six weeks. The compounds were similar to those used in our human experiments and consisted of six irritating and 12 non-irritating compounds. The animals then were retested after an interval of one week with six other compounds and the degree of reactions compared with three animals which had never been tested before.

No essential difference in the reaction of the two animal groups to these six compounds could be elicited. This experience is in accord with the statement of Rostenberg and Haeberlin,[8] who showed that eczematous types of skin sensitization are questionable in dogs, rabbits and white mice.

TABLE IV.
EXPERIMENT C

Test Subjects	Number of Various Reactions					Average I.I.
	0	+	++	+++	++++	
Old reactors	45	24	26	17	8	1.33
Trained reactors	42	26	27	19	6	1.34
New subjects	193	38	6	3	0	0.25

TABLE V.
ANIMAL EXPERIMENTS

Test Subjects	Number of Various Reactions				Average I.I.
	0	+	++	+++	
3 Exposed animals	12	5	1	0	0.4
3 New animals	13	4	1	0	0.3

Conclusions

DIVERGENT results of patch tests with two well known plasticizers obtained by us and by Sunderman and Haag led to a series of investigations which we feel demonstrated the cause for this discrepancy. In our recheck experiments the results of Sunderman and Haag were confirmed on a group of test subjects consisting of students most of whom had never before been used in skin testing experiments. Analysis of our previous records showed that our previous results were obtained with test subjects most of whom had served in this capacity many times before and some of whom admitted on questioning a definite increase in their skin irritability. The difference between the skin irritability of persons previously exposed to many skin tests and new subjects could be clearly demonstrated by us with six compounds none of which had been tested on those subjects before and none of which were considered sensitizing. In another experiment we could demonstrate that the skin irritability could indeed be increased comparatively quickly in a group of new subjects by subjecting them to repeated patch tests over a short period of time. We finally could show that this altered skin irritability was quite nonspecific and could be demonstrated with various chemically unrelated non-sensitizing compounds.

From these results we must conclude that some of our previously published results

may well have been erroneous and may have been influenced by an increased skin irritability developed in persons used repeatedly for patch tests. We feel that the development of this nonspecific skin irritability has not been recognized properly in the literature and that it constitutes a serious source of errors in prophetic patch test procedures. In order to avoid this source of errors two procedures are available. The safest means would be to test each compound on an entirely new group of subjects. That would involve very large groups of volunteers and in our case would have called for at least 5000 test subjects during the last seven years. Adoption of this rule would be even less feasible in instances where the sampling group must be enlarged to 200 persons in order to assure a certain statistically valuable maximum permissible percentage of reactions in a large population.[9] The other alternative, and the one which we have adopted, is to continue our skin tests in a similar manner as before but to retest all those compounds which give positive reactions on a group of new subjects before we accept these results as final. Of 292 compounds examined in the past seven years 69.2% proved non-irritating and 78.4% were non-sensitizing. We feel no need to reëxamine those tests on a group of new individuals. Of a total of 90 compounds, 23.6% proved slightly irritating; 4.8%, moderately irritating; and only 2.4%, severely irritating. Those compounds are now being retested on new groups of subjects who have never been patch-tested before, in order to reëvaluate their irritating and sensitizing properties.

References

1. Rostenberg, A., Jr.: The Patch Test, *GP*, 10:104, 1955.
2. Sulzberger, M.D.; Baer, R. L.; Kanof, A., and Lowenberg, C.: Methods for the Rapid Evaluation of the Beneficial and Harmful Effects of Agents Applied to the Human Skin. *J. Investig. Dermat.*, 7:227, 1946.
3. Schwartz, L.: Occupational Dermatoses. Industrial Hygiene and Toxicology, (F. A. Patty, Editor) Interscience Publishers, Inc., New York City, 1948, Vol. 1. pp. 360-364.
4. Schwartz, L., and Peck, S.: The Irritants in Adhesive Plaster, *Pub. Health Rep.*, 50:811, 1935.
5. Mallette, F. S., and von Haam, E.: Studies on the Toxicity and Skin Effects of Compounds Used in the Rubber and Plastics Industries. I. Accelerators, Activators, and Antioxidants. *AMA Arch. Indus. Hyg.*, 5:311, 1952.
6. Mallette, F. S., and von Haam, E.: Studies on the Toxicity and Skin Effects of Compounds Used in the Rubber and Plastics Industries. II. Plasticizers. *AMA Arch. Indus. Hyg.*, 6:231, 1952.
7. Sunderman, F. W., and Haag, H. B.: Irritating and Sensitizing Effects of Two Polymeric Plasticizers. Studies on Effects of Paraplex G-25 and Paraplex G-40 on the Skin of Human Subjects. *AMA Arch. Indus. Hyg.*, 9:210, 1954.
8. Rostenberg, A., Jr., and Haeberlin, J. B.: Studies in Eczematous Sensitizations. III. The Development in Species other than Man or the Guinea Pig. *J. Investig. Dermat.*, 15:233, 1950.
9. Henderson, C. R., and Riley, E. C.: Certain Statistical Considerations in Patch Testing. *J. Investig. Dermat.*, 6:227, 1945.

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION
14125 Prevost
Detroit 27, Michigan

Please send the following Hygienic Guides at $.25 each:

_____ copies Aniline
_____ copies Benzol
_____ copies Formaldehyde
_____ copies Hydrogen Sulfide
_____ copies Sulfur Dioxide
_____ copies Acetaldehyde
_____ copies Amyl Acetate
_____ copies Butyl Alcohol
_____ copies Cadmium
_____ copies Carbon Tetrachloride

Name _____

Address _____

Street and No. _____

City _____ Zone _____ State _____

Remittance must accompany orders for less than $2.00. Discount of 20% on orders of five or more Guides. Special discounts on orders of 100 or more Guides.

✦ President's Page

THIS PRESIDENT'S page will summarize for the membership certain affairs of the Association. These, along with other activities, were reviewed by your Board of Directors at the meeting in Pittsburgh on November 16. Reports of committee activities are most encouraging and real progress is being made with work of the Technical Committees. Of equal importance is progress of the Standing Committees. Some of the details appear below.

The office of the Executive Secretary has been moved to Detroit and the part-time paid executive secretary has assumed his duties and responsibilities. Office and other facilities for handling association business are being developed by the Executive Secretary.

Plans for the Philadelphia meeting are progressing satisfactorily. The Program Committee reports that papers are coming in and the preliminary program will be worked out in the near future. Details for the meeting are being developed by the Conference and associated committees.

The report of the Editor of the QUARTERLY is most encouraging. The September issue of the QUARTERLY showed again that this publication is paying its own way and staying out of the red. Circulation and advertising have also been increased. The Quarterly also is receiving adequate material for publication. AIHA is indebted to the editorial staff for a job well done.

The Sub-Committee on Fellowships has for some time been concerned with establishing funds for training in Industrial Hygiene. The Committee has now completed a brochure to be used in soliciting funds. Advice from a financial institution is being obtained and AIHA should soon be in a position to solicit such funds. Real progress is being made and it has taken a lot of hard work on the part of the Committee. Action was taken by the Board of Directors to give this subcommittee full committee status.

In the Technical Committees, progress is reported all the way around. The first set of Hygienic Guides has been published and a schedule has been established for the publication of future Guides.

The Radiation Committee is preparing a manual and reports that the table of contents is now considered complete and assignment for completion of various chapters has been made among members of the Committee. It is anticipated that this manual should be completed in the form proposed by the Committee by April, 1956.

Work on a manual by the Noise Committee is also showing good progress. Several chapters have been completed and it is hoped that the manual will be completed in 1956.

Discussions and reports at the Board meeting indicate that your Committees and Board members are working. Every member of AIHA should take pride in what the Association has accomplished over the past few years and what it plans for the future. I think that these accomplishments are a measure of the interest and support given by the members—it could not have been done without it.

—N. V. HENDRICKS

Publications

THE U. S. Atomic Energy Commission has published its proposed "Standards for Protection Against Radiation" in the Federal Register. July 16, 1955, pp. 5101 to 5105, 15 cents, Supt. of Documents, Wash. 25, D. C.

HYGIENIC GUIDE SERIES

ANILINE

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 5 parts of vapor per million parts of air, by volume (ppm).[1]

(1) *Basis of Recommendation*: Human and animal data indicate that cyanosis will not develop from inhalation below this level. This value is probably not very accurate.

B. SEVERITY OF HAZARD:

(1) *Health*: Acute hazard is high both from skin absorption and from inhalation. Chronic hazard is nil and of doubtful existence.

(2) *Fire*: Slight. Flash point is 71°-77°C (160-170°F) (closed cup).

C. SHORT EXPOSURE TOLERANCE: Uncertain, but probably 50-100 parts per million can be tolerated for 60-minutes.[6] This will depend on the extent of skin contact and also upon the susceptibility of the individual.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown.

II. Significant Properties

Aniline is a colorless (darkens readily on exposure to air), oily liquid, with an aromatic amine-like odor.

Chemical formula:	$C_6H_5NH_2$
Molecular weight:	93
Specific gravity:	1.022 (20°/4°C)
Boiling point:	184.2°C.
Relative density:	3.22 (air = 1)
Vapor pressure:	15 mm Hg at 77°C
1 ppm of vapor (25°C and 760 mm Hg):	0.0038 mg/liter
1 mg/liter (25°C and 760 mm Hg):	263 ppm
Odor threshold:	About 0.5 ppm
Solubility:	In acids and most organic solvents; in water, 3.4%

III. Industrial Hygiene Practice

A. RECOGNITION: Used in many chemical industries in manufacture of dyes, pharmaceuticals, photographic developers, etc. Causes cyanosis (bluish color of skin) from inhalation of vapor, skin contact, or swallowing. Usually noticed first on lips, fingernails, and lobes of the ear. The hazard is principally an acute one. There is litle or no chronic effect from aniline itself, although many derivatives do have chronic effects.

B. EVALUATION OF EXPOSURES:

(1) *Instrumentation*: Collection by scrubbing through spectroscopically pure alcohol in an all-glass scrubbing device, and estimating by ultraviolet spectroscopy.

(2) *Chemical*: Collection by scrubbing through dilute acid, followed by diazotization and comparison with colored standards.[2]

C. RECOMMENDED CONTROL PROCEDURES: Maintain workroom atmospheres below 5 ppm with enclosure and/or ventilation of processes. Prevent skin contact through the use of personal protective equipment. Use routine showers at the end of each day, and, daily, clean uniforms and underclothing. Use personal respiratory protective equipment when working around spills or entering open tanks, and auxiliary ventilation, in addition to such equipment, when entering closed tanks.

IV. Specific Procedures

A. FIRST AID: Immediately remove all contaminated clothing, including shoes, and wash entire body with plenty of soap and water. Scrub hands. Clean out finger and toe nails. Shampoo hair. Clean out nostrils and ear canals. Put to bed and give oxygen.[5] In case of eye splashes, flush with water for at least 10 minutes.

B. BIOCHEMICAL ASSAY: None.

C. SPECIAL MEDICAL PROCEDURES: In aniline poisoning, determine methemoglobin

and repeat every 3-6 hours for 18-24 hours. Two commonly used methods are those of Vanderbelt, et al,[7] and of Evelyn and Malloy.[3] Repeat showers and skin cleaning if methemoglobin appears to rise after 3-4 hours. If methemoglobin is greater than 40%, give intravenous infusion of 500 cc of 5% glucose. Collect and measure aniline excretion in urine. Hill's method[4] has been used for this purpose. Give oxygen as long as any symptoms of headache or weakness persist. Use a high carbohydrate, bland diet for 24 hours. The former use of methylene blue appears not to have been effective or necessary. Preplacement examinations should be directed toward carefully evaluating the individual for alcoholism, and liver, renal, or blood diseases. The presence of any of these should prohibit assignment to jobs offering aniline exposure.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:521, 1955.
2. Elkins, H. B.: Chemistry of Industrial Toxicology. John Wiley and Sons, Inc., New York, 1950.
3. Evelyn, K. A., and Malloy, H. T.: *Jour. of Biol. Chem.*, 126:655, 1938.
4. Hill, D. C.: *Arch. of Ind. Hyg. and Occ. Med.*, 8:347, 1953.
5. Mangelsdorf, A. F.: *Indus. Med. & Surg.*, 21:395, 1952.
6. Manufacturing Chemists Association: Chemical Safety Data Sheets, SD-17, 1947.
7. Vanderbelt, J. M., et al: *Jour. of Phar. and Exp. Ther.*, 80:31, 1944.

SULFUR DIOXIDE

I. Hygienic Standards

A. Recommended maximum atmospheric concentration (8 hours): 10 parts of gas per million parts of air, by volume (ppm).[2]

(1) *Basis for Recommendation*: Control of irritation to eyes and respiratory tract of humans.

B. Severity of hazards:

(1) *Health*: moderate for both chronic and acute exposures. Effects are primarily irritation of mucous membranes. Endurable concentrations can be tolerated for long periods of employment without appreciable danger to health. In a concentration range of 1-10 ppm, there is an increase in respiratory and pulse rate and decrease in depth of respiration in unacclimatized individuals. Acclimatized individuals, working daily in concentrations in excess of 10 ppm do not show these changes on exposure to 5 ppm.[1,6,8]

(2) *Fire*: none.

C. Short exposure tolerance: The odor threshold is approximately 3 ppm.[9] Eye irritation occurs at approximately 20 ppm; 50 to 100 ppm is considered the maximum concentration for ½ to 1 hour exposure.[7]

D. Atmospheric concentration immediately hazardous to life: 400-500 ppm considered dangerous for even short periods of exposure.[7] Exposure to unendurable concentrations is not necessarily hazardous if escape is made within a few minutes.

II. Significant Properties

Sulfur dioxide is a pungent, suffocating, irritating, colorless gas having an odor associated with burning sulfur.

Chemical formula:	SO_2
Molecular weight:	64
Boiling point:	-10.0°C
Vapor pressure:	3.2 atm. at 20°C
Relative density:	2.2 (air = 1)
Solubility:	Water: 22.8 gm/100 ml 0°C. Soluble in ethyl alcohol, ethyl ether chloroform, acetic acid, and sulfuric acid.
Odor threshold:	0.009 mg/1 (3.4 ppm)[9]
1 ppm of gas (25°C and 760 mm):	0.0026 mg/1
1 mg/1 of gas (25°C and 760 mm):	382 ppm

III. Industrial Hygiene Practice

A. Recognition: By its odor and irritant effects. Major uses are in the manufacture of sulfuric acid, as a bleach, refrigerant, selective solvent in lubricating oil manufacture, fumigant, casting of nonferrous metals, food processing. It has been of interest in air pollution studies.

B. EVALUATION OF EXPOSURES:

(1) *Instrumentation*: There are continuous automatic recorders available, as the Titrilog (CED Instruments, Inc., Pasadena 15, Calif.) and the Thomas Autometer (Leeds and Northrup Co., Philadelphia 44, Pa.). For spot sampling, the MSA Sulfur Dioxide Detector is satisfactory. (Mine Safety Appliances Co., Pittsburgh 8, Pa.)

(2) *Chemical method*: Absorption in alkali and titration with iodine or absorption in iodine-potassium iodide solution and titration with thiosulfate.[4] Absorption in glycerol-alkali solution and measurement of color developed with formaldehyde-fuchsin, or buffering to pH 4 and determination by polarography.[10] Collection in neutral hydrogen peroxide and estimation of resulting acid.[5]

C. RECOMMENDED CONTROL PROCEDURES: Maintain workroom exposures below 10 ppm by means of process enclosure and/or ventilation. Discharge to the atmosphere through high stacks has been an effective method of disposition in a number of industries. Protection for eyes and respiratory tract is recommended if atmospheric concentrations cannot be maintained below 10 ppm.

IV. Specific Procedures

A. FIRST AID: Removal to a non-contaminated location should be prompt. Artificial respiration may be needed and pure oxygen may be supplied if breathing is labored. Medical procedures are largely supportive with careful attenion to the possibilities of eye and pulmonary sequelae.[3]

B. BIOCHEMICAL ASSAY: None.

C. SPECIAL MEDICAL PROCEDURES (including preplacement): In preplacement consider existing chronic respiratory conditions which might be aggravated by coughing.[3]

V. Literature References

1. AMDUR, M. O., et al: Lancet, 2:758, 1953.
2. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:522, 1955.
3. American Petroleum Institute: API Toxicological Review—Sulfur Dioxide. American Petroleum Institute, New York, 1948.
4. ELKINS, H. B.: The Chemistry of Industrial Toxicology. John Wiley and Sons, New York, 1950.
5. GOLDMAN, F. H., and JACOBS, N. B.: Chemical Methods in Industrial Hygiene. Interscience Publishers Inc., New York, 1953.
6. GREENWALD, I.: *Arch. of Ind. Hyg. and Occup. Med.*, 10:455, 1954.
7. HENDERSON, Y., and HAGGARD, H. W.: Noxious Cases. Reinhold Publishing Corp., New York, 1943.
8. KEHOE, R. A., et al: *J. Ind. Hyg.*, 14:159, 1932.
9. MCCORD, C. P., and WITHERIDGE, W. M.: Odors, Physiology and Control, p. 53. McGraw-Hill Book Co., Inc., New York, 1949.
10. PAULUS, H. J., et al: Determination of Sulfur Dioxide in Atmospheric Samples. *AIHA Quarterly*, 15:277, 1954.

BENZENE (BENZOL)

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 35 parts of vapor per million parts of air, by volume (ppm).[1]

(1) *Basis for Recommendation*: Toxicological observations on animals and human experience in industry.

B. SEVERITY OF HAZARDS:

(1) *Health*: Moderate for acute exposure; high, for chronic. Absorption occurs chiefly by inhalation. High concentrations irritate the respiratory tract and produce narcosis. Repeated exposure to benzene may cause bone marrow damage, resulting in a decrease in the circulating white blood cells, platelets, and red blood cells. Individual susceptibility varies widely, with the possibility that an occasional individual may be affected, even with an atmospheric exposure of 35 ppm. Dermatitis may result from repeated skin contact. Gerarde[3] has recently shown that alkyl derivatives (toluene) of benzene do not produce the bone marrow effects of benzene in rats.

(2) *Fire*: High. Explosive limits are 1.4 to 6.8 per cent by volume. Flash point is -24°C (-11.2°F) (closed cup).

C. SHORT EXPOSURE TOLERANCE: 3,000 ppm is reported endurable for 60 min.[5] This may be too high. 7,500 ppm is dangerous in 30-60 min.[5]

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: 20,000 ppm is reported fatal in 5-10 min.[5] This may be too high.

II. Significant Properties

Benzene is a flammable, colorless, odorous liquid.

Chemical formula:	C_6H_6
Molecular weight:	78
Specific gravity:	0.879 (20°C./4°C)
Boiling point:	80.1°C
Relative density of vapors:	2.7 (air = 1)
Vapor pressure:	100 mm of Hg at 26°C
Solubility:	In most organic solvents.
1 ppm of vapor: (25°C. and 760 mm Hg):	0.0032 mg/liter
1 mg/l of vapor (25°C. and 760 mm Hg):	313 ppm

Note: Benzene, an aromatic hydrocarbon, is to be carefully distinguished from benzine, a petroleum distillate containing mixed hydrocarbons (such as hexane and pentane) in uncertain proportions. However, some commercial petroleum solvents, including gasoline, may contain appreciable quantities of benzene.

III. Industrial Hygiene Practice

A. RECOGNITION: Benzene may be usually recognized by its characteristic odor. It is an excellent solvent for a wide variety of gums, resins, fats, alkaloids and rubber, and is frequently used in combination with other solvents. It is present, to some extent, in most gasolines and is a common ingredient of paint and varnish removers.

B. EVALUATION OF EXPOSURES:

(1) *Instrumentation*: Direct determination by the use of the aromatic Hydrocarbon Detector (Mine Safety Appliances Co., Pittsburgh 8, Pa.) or by the Davis Vapotester Model M-6 (Davis Emergency Equipment Co., Newark, New Jersey). Collection by scrubbing through spectroscopically pure alcohol in an all-glass device, followed by ultraviolet spectroscopy.

(2) *Chemical Method*: Collection by absorption on silica gel, followed by nitration and comparison with prepared standards,[2] or by polarography.[4]

C. RECOMMENDED CONTROL MEASURES: Maintain workroom atmospheres below 35 ppm by means of process enclosure and/or ventilation. Practice substitution using less toxic solvents. Suggestions are petroleum aliphatic hydrocarbons, toluene, and xylene. Prevent skin contact through the use of protective clothing, made of nitrile type of rubber, (Butaprene, Chemigum, Hycar, Krynac, Paracril) or Neoprene. Use chemical type goggles.

IV. Specific Procedures

A. FIRST AID: Remove from exposure; remove contaminated clothing, cleanse skin, eyes, etc.

B. BIOCHEMICAL ASSAY: The measurement of urinary sulfates has been suggested as a control procedure.[6] While this is a measure of benzene exposure, it tells nothing about the health of the individual and is of only limited use as a control procedure, particularly in lowgrade chronic intoxication.

C. SPECIFIC MEDICAL PROCEDURES:

(1) *Preplacement*: Individuals with blood abnormalities, with alcoholism, or with liver or kidney disease should not be exposed. Physical and laboratory examinations are required for proper evaluation.

(2) *Periodic Examination*: Practice a rigid program of routine physical examinations of all personnel exposed. This should include a complete blood count at intervals no greater than every two months (frequency may be decreased if regular air analyses show the absence of a benzene hazard). Common complaints referable to the nervous system are: headache, dizziness, irritability, restless sleep, tremors, gastrointestinal symptoms, or loss of appetite, dryness of the mouth and throat, and intestinal colic. Evidences of bone marrow damage are: decrease in white blood cells and platelets, decrease of red blood cells, bleeding from mucous membranes, subcutaneous hemorrhages, and anemia.

Dr. L. J. Goldwater and Dr. H. W. Gerarde served as consultants to the Hygienic Guides Committee in the preparation of this Guide.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:522, 1955.
2. ELKINS, H. B.: Chemistry of Industrial Toxicology. John Wiley and Sons, Inc., New York, New York, 1950.
3. GERARDE, H. W.: Paper presented at the 1955 American Industrial Hygiene Association meeting, Buffalo, N. Y. (To be published).
4. GISCLARD, J. B.: Private Communication (American Cyanamid Co., New York, N. Y.).
5. PATTY, F. A., (editor): Industrial Hygiene and Toxicology, Volume 2. Interscience Publishers, New York and London, 1949.
6. YANT, W. P., et al: *J. Ind. Hyg. and Tox.*, 18:69, 1936.

HYDROGEN SULFIDE

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 20 parts of gas per million parts of air, by volume (ppm).[1,3]

(1) *Basis for Recommendation*: Human experience plus animal studies.[4]

B. SEVERITY OF HAZARDS:

(1) *Health*: high for acute exposures; moderate for chronic. There is a prompt and direct irritating effect on the conjunctiva and respiratory tract. Olfactory fatigue can occur within 2-15 minutes at 100 ppm. At high concentrations (1000-2000 ppm), asphyxiation may occur very quickly due to interference with oxygen transport and utilization in the body. No sequelae if recovery occurs.

(2) *Fire*: moderate. Ignition temperature 292°C. Explosive limits are 4.3% to 45.5% by volume.

C. SHORT EXPOSURE TOLERANCE: 50-100 ppm cause slight conjunctivitis and respiratory tract irritation after 1 hour, with marked conjunctivitis and respiratory tract irritation after 1 hour at concentrations of 200-300 ppm (2).

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: 500-700 ppm cause loss of consciousness and possible death in 30-60 minutes. Unconsciousness, respiratory failure, and death occur rapidly at concentrations of 700-900 ppm.

II. Significant Properties

This extremely unpleasant, colorless gas has a characteristic rotten egg odor at lower concentrations.

Chemical formula: H_2S
Molecular weight: 34.08
Boiling point: -60.1°C
Vapor pressure: 17.7 atm. at 20°C
Relative density: 1.192 (air = 1)
Solubility: Water: 437 ml/100 ml, 0°C. Slightly soluble in ethyl alcohol, soluble in carbon disulfide
Odor threshold: 0.13 ppm[2]
1 ppm of gas (25°C and 760 mm): 0.00139 mg/l
1 mg/l of gas 25°C and 760 mm): 717 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: Sense of smell at low concentrations. Odor not reliable at high concentrations and olfactory fatigue occurs quickly. Industrial exposures may occur in petroleum refining, especially of high sulfur crudes, viscose rayon manufacture, sewage disposal plants, chemical laboratories, and as a side product of many reactions and processes.

B. EVALUATION OF EXPOSURE:

(1) *Odor*: Unreliable because of olfactory fatigue. Threshold is 0.13 ppm. Faint but readily perceptible at 0.77 ppm. Easily noticeable at 4.6 ppm. Strong, unpleasant, but not intolerable at 27 ppm.[2]

(2) *Instrumentation*: There are continuous, automatic detecting devices available such as the A.I.S.I. Hydrogen Sulfide Sampler (Research Appliance Co., Pittsburgh 9, Pa.), Recording H_2S Analyzer (Rubicon Company, Pittsburgh 32, Pa.), Titrilog (CEC Instruments, Inc., Pasadena 15, Calif.), Supersensitive Analyzer (Taller and

Cooper, Brooklyn 1, N.Y.), H_2S Indicator (Davis Emergency Equipment Co., Inc., Newark 4, N. J.), and others. For spot samples, especially for field work, lead acetate papers may be used or silver cyanide detector tubes (Hydrogen Sulfide Detector, Mine Safety Appliances Company, Pittsburgh 8, Pa.).

(3) *Chemical method*: Either absorption in a solution of a cadmium salt and iodometric determination of the cadmium sulfide, absorption in alkaline zinc acetate solution and subsequent colorimetric determination, or, in the absence of oxidizing or reducing gases, absorption in iodine-potassium iodide solution and iodometric determination.[5]

C. RECOMMENDED CONTROL PROCEDURES: Maintain workroom atmospheres below 20 ppm by means of process enclosure and/or ventilation. Disposition must not constitute a nuisance or hazard to the public. Small amounts may be flared or burned in a furnace.

Larger amounts may justify concentration and recovery as elemental sulfur. Eye and respiratory protective equipment should be used in concentrations exceeding 20 ppm.

IV. Specific Procedures

A. FIRST AID: Acute poisoning is a medical emergency. Removal to a non-contaminated location should be prompt. Summon medical assistance. Keep patient warm and at rest. Artificial respiration should be promptly instituted if breathing has ceased. Oxygen or oxygen-CO_2 inhalation is recommended, continuing after spontaneous breathing has returned, as the high oxygen concentration aids in the destruction of H_2S.[2]

B. BIOCHEMICAL ASSAY: None.

C. SPECIAL MEDICAL PROCEDURES: Preplacement examinations should be thorough. Workers with any severe ailment, including eye and nervous diseases, should not be employed on operations involving H_2S exposures. Treatment for acute exposures are supportive. Eye irritation may be severe. Olive oil or 1:1000 epinephrine solution have been recommended for the eyes with local anesthetic and hot or cold compresses if the pain is acute.[2]

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:522, 1955.
2. American Petroleum Institute: API Toxicological Review—Hydrogen Sulfide, New York, 1948.
3. American Standards Association: American Standard Z37.2—1941.
4. BARTHELEMY, H. L.: *J. Ind. Hyg. Tox.*, 21:141, 1939.
5. JACOBS, M. B.: The Analytical Chemistry of Industrial Hazards, Poisons, and Solvents, Vol. I, 2nd Ed. Interscience Publishers, Inc., New York, 1949.

FORMALDEHYDE

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 5 parts of gas per million parts of air,[1] and 10 parts of gas per million parts of air (ppm), by volume.[2]

(1) *Basis for Recommendation*: Irritant properties to eyes and respiratory organs of humans.[3]

B. SEVERITY OF HAZARDS:

(1) *Health*: Moderate for both acute and chronic exposures. Effects are primarily irritation of mucous membranes. It is a skin irritant, and may produce contact dermatitis.

(2) *Fire*: Slight. Usually a water solution (formalin) is employed, containing 37% by weight of formaldehyde, which is further diluted before use.

C. SHORT EXPOSURE TOLERANCE: In animal experiments,[4] cats exposed to 200 ppm for 3.5 hours quickly recovered without injury.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: 650 ppm.[4]

II. Significant Properties

Formaldehyde is a gas with an intensely irritating odor. It is very reactive and polymerizes readily.

Chemical formula: HCHO
Molecular weight: 30.03
Boiling point: -21°C.
Relative density: 1.03 (air = 1)

1 ppm of vapor (25°C and 760 mm Hg):	0.001227 mg/liter
1 mg/liter (25°C and 760 mm Hg):	815 ppm
Solubility:	In water, and most organic solvents

"Formalin" is an aqueous solution containing 37-38% by weight of formaldehyde and, usually, 10-15% methanol to prevent polymerization.

III. Industrial Hygiene Practice

A. RECOGNITION:

(1) By its odor. It is used in the chemical and textile industries, in synthetic resin manufacture, in tanneries, in embalming, and as a preservative and disinfectant.

(2) By its irritant action on the conjunctiva and on the mucous membranes.

B. EVALUATION OF EXPOSURES:

(1) *Instrumentation*: Collection in dilute potassium hydroxide solution and estimation by polarography.[3]

(2) *Chemical*: Absorption in a sodium bisulfite solution and estimation by iodometric titration.[5]

C. RECOMMENDED CONTROL PROCEDURES: Maintain workroom atmospheres below 5 ppm by means of enclosure and/or ventilation. Operations which permit the escape of free formaldehyde into the workroom air should be provided with local exhaust ventilation. Drying or curing ovens in which formaldehyde is driven off from the material processed should have adequate exhaust to outer air. Care must be exercised in the discharge of these vapors to prevent community atmospheric pollution.

IV. Specific Procedures

A. FIRST AID: If a solution containing formaldehyde is spilled on the skin or splashed into the eyes, the affected part should be flushed immediately with clean, fresh water.

B. BIOCHEMICAL ASSAY: None.

C. SPECIAL MEDICAL PROCEDURES (including preplacement): Individuals who have a strong history of allergic disease, such as hay fever and asthma, and those with a history of skin disorders should be placed on jobs involving formaldehyde exposure only after very careful medical examination of the individual and his history. Generally speaking, exposure to formaldehyde is contraindicated for these individuals.

Note: John H. Fahy served as Consultant to the Hygienic Guides Committee in the development of this Guide.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:522, 1955.

2. American Standards Association: Allowable Concentration of Formaldehyde. Standard Z37.16—1944.

3. BARNES, E. C. and SPEICHER, H. W.: Jour. of Ind. Hyg. & Tox., 24:10, 1942.

4. FLURY, F. and ZERNIK, F.: Schadliche Gase und Dampfe. Julius Springer, Berlin, 1931.

5. GOLDMAN, F. H. and YAGODA, H.: *Ind. and Eng. Chem.*, Anal. Ed., 15:377, 1943.

Because of space limitations, it is impossible to list all methods of exposure evaluation. The selections have been made on the basis of current usage, reliability, and applicability to the usual industrial type of exposure. Any specific evaluation and/or control problem will involve professional judgment. This can best be done by professional industrial hygiene personnel.

Respiratory protective devices are commercially available. Their use, however, should be confined to emergency or intermittent exposures and not relied upon as primary means of hazard control.

HYGIENIC GUIDES COMMITTEE

WILLIAM E. MCCORMICK, *Chairman*
FRANCIS F. HEYROTH, M.D.
HERVEY B. ELKINS, Ph.D.
DAVID W. FASSETT, M.D.
WILLIAM B. HARRIS
MELVIN W. FIRST, Sc.D.
H. E. STOKINGER, Ph.D.
H. E. SEIFERT
CLYDE M. BERRY, Ph.D.

Hygienic Guide sheets may be obtained from the American Industrial Hygiene Association, 14125 Prevost, Detroit 27, Michigan, at 25c each. An order blank may be found on page 329.

✦ Selected Titles and Abstracts

—FROM FOREIGN EXCHANGE JOURNALS

THE FOLLOWING is a partial list of articles, by titles and authors, from journals received by the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION since the June, 1955 issue of the QUARTERLY in exchange for copies of the QUARTERLY.

Additional information regarding any of the journals or articles may be obtained from: CARROL S. WEIL, Senior Industrial Fellow, Mellon Institute of Industrial Research, 4400 Fifth Avenue, Pittsburgh 13.

I. ARHIV ZA HIGIJENU RADA (JUGOSLAVIA). Vol. 6, No. 1 (1955).

The Influence of Chronic Exposition to Lead on Blood Pressure. A. Jamnicki, M. Kilibarda, and N. Ilijev, pp. 23 to 27.

The authors measured systolic blood pressure in a group of 46 workers in a storage battery factory exposed to 0.2 to 0.4 mg/m^3 lead in the air. They found no evidence of increased blood pressure in these men *vs.* a similar size control group.

The Design and Operation of an Experimental Gas Chamber. V. B. Vouk, Z. Topolnik, F. Valić, and O. A. Weber, pp. 29 to 33.

II. ARHIV ZA HIGIJENU RADA (Jugoslavia). Vol. 6, No. 2 (1955).

Four Cases of Metol Poisoning. V. Palmović and Jelena Frketić, pp. 135 to 142.

After a brief account of the chemical properties of metol (methyl-p-aminophenol) and its use, the authors describe local lesions in occupational metol poisoning and the way in which they occur. Symptoms of experimental as well as four cases of accidental metol poisonings are discussed. The authors do not consider the formation of methemoglobin in blood very probable. Minimal lethal dose for men by rectal application is estimated to be 0.2 gm/kg.

Anatomy Without Dissection: Evaluation of Body Composition in Vivo. Josef Brozek, pp. 151 to 163.

The problem of body composition, with special reference to body fat has been examined in detail with special reference to the logic and arithmetic of the formulae used in the calculation of body compartment. While the biochemical and biophysical approaches are more elegant, states the author, and more fundamental, it is the antropometric analysis which is particularly suitable for much of the research in the field and in the clinic. In laboratory investigations the combination of all three approaches yields the fullest information.

Stimulation and Aggravation in Audiometry. M. Prazić, pp. 165 to 180.

In view of the data from the literature and his own experience, the author discusses this problem in audiology. Classical otological methods are not considered reliable and satisfactory, audiologic analysis may sometimes give good results; in most cases, however, the exact verification can only be obtained by using the methods of advanced and objective audiometry.

In verifying aggravation special methods of supraliminal audiometry and objective audiometry should be used because the routine audiometric tests rarely prove successful.

III. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 31, No. 6 (1955).

A Study on Blood Findings, Liver Function Tests and Histological Appearance in Experimental Lead Poisoning and Relationship Among Them. Masao Motouchi, pp. 371 to 384.

Change of Serum Protein and its Fractions in Experimentally Induced Lead Poisoning. Takero Sakaguchi, pp. 385 to 397.

IV. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 31, No. 7 (1955).

Studies on the Inactive Hemoglobin. I. Takeo Suzuki and Kifyofumi Ishikawa, pp. 433 to 438.

By the 1946 Van Slyke method the amount of inactive hemoglobin in normal blood is in the order of 1% of the total blood pigments. It is increased in workers exposed to CO or to monochloro-monobromomethane.

V. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 31, No. 8 (1955).

Studies on Air Pollution. I. A Survey on Air Pollution in Tokyo District Observed Through the Concentration of SO_2 in the

Atmospheric Air. S. Minami et al., pp. 507 to 523.

On the Occupational Hazards in Working with Portable Vibrating Tools. II. On the Raynaud's Phenomenon of Workers. Toyohiko Miura, Mituo Moricoka, Kikuzi Kimura, Yahatiro Matusika and Tei Taguti, pp. 524 to 531.

An Experimental Study on Chlorine Gas Poisoning; Particularly on Leucocytosis and Change of Tissue Respiration as well as Tissue Structure. K. Nishimura, pp. 532 to 537.

Studies on Ear Defenders: Attenuation Power of Roken Type Ear Plugs, (Report 5.) Mitsuo Morioka, pp. 545 to 553.

The Roken type ear plug, when properly fitted, afforded the attenuation of 15 to 20 db in the low frequency range, 20 to 30 db in the middle frequency range, and 30 to 35 db in the high frequency range.

◆ News of Local Sections

Philadelphia

AT THE SEPTEMBER meeting GILBERT B. MEYERS, M.D., Supervising Physician for the Philadelphia operations of the Electric Storage Battery Company described the results of two years of lead exposure in the manufacture of lead acid storage batteries. DR. MEYERS was concerned with the medical aspects of control of lead and he showed what results could be obtained with a program based on urine and blood lead analysis.

LUCIEN BROUHA, M.D., Head, Physiology Division, Haskell Laboratory for Toxicology and Industrial Medicine, DuPont Company, discussed "Heat and Physiological Stress" at the November meeting. DR. BROUHA showed the relationship between heart rate and temperature variations. Under heat stress there is a marked increase in heart rate.

Chicago

MEETINGS this year are being held the first Wednesday of each month on the second floor of the Toffenetti Restaurant, 65 W. Monroe Street. AIHA or associate members from other areas who may be in Chicago on meeting dates are invited to attend.

JOHN F. EGE, JR., Director of Industrial Hygiene and Safety, Argonne National Laboratory, was speaker at the September meeting. He discussed "Industrial Hygiene Problems at an Atomic Energy Laboratory." After outlining the organization of the group he directs, he related some of the problems encountered and the instrumentation required for their evaluation and control. Mention was also made of occasional problems presented by persons living near the laboratory.

AIHA executive secretary, George D. Clayton, spoke at the October meeting on "The Detroit-Windsor Joint Air-Pollution Survey." His interesting talk, accompanied by slides, portrayed the problems encountered in sampling, analysis and interpretation of the findings.

Many members were well rewarded by braving a combination of rain, sleet and snow on November 2, to hear ROBERT PRING, Technical Director, Wheelabrator Corporation. Particular attention was given to the capture of effluents from furnace operations. Slides gave collection efficiency data for various types of cloth fabric. MR. PRING stated that the introduction of suitable absorbents into the airstream to remove gaseous contaminants prior to filter collection has interesting possibilities.

Northern California

ON OCTOBER 11, the Northern California section met at Spenger's Fish Grotto in Berkeley and heard ROBERT T. LEGGE, M.D., give an interesting discussion of his experiences in industrial hygiene and occupational medicine in California. DR. LEGGE, winner of the 1951 Knudsen Award, is a charter member of the Ramazzini Society and an honorary member of the International Permanent Committee on Occupational Medicine.

Metropolitan New York

"SHOULD the Radiation Safety Specialist be Licensed?" was discussed at the Metropolitan New York section meeting October 31, in the Union Carbide and Carbon Building, 30 E. 42nd Street. Speakers

were S. ALLEN LOUGH, Ph.D., Senior Physicist (Isotopes) Francis Delafield Hospital, New York City, and HANSON BLATZ, E. E., P.E., Chief, Radiation Branch, Health & Safety Division, New York Operations Offices, AEC.

Pittsburgh Section News

THE SEPTEMBER 27th meeting of the Pittsburgh Section was held at the Bureau of Mines Auditorium in Pittsburgh.

"Microscopy of Industrial Dust" was the subject presented by GERMAIN C. CROSSMON, industrial hygienist, and head of the Chemical and Biological Microscopy Section, Bausch & Lomb Optical Company, Rochester, New York. The talk, with lantern slides, covered the uses of the dark field, phase, polarized light technique for dust counting and identification purposes.

✦ *In the News*

DR. JOSEPH SHILEN is now Chief of Preventive Medicine at Olmstead Army Air Base, Middletown, Pennsylvania. He was formerly Director of the Bureau of Industrial Hygiene, State Department of Health, Commonwealth of Pennsylvania.

JACOB S. SHARRAH is now Industrial Hygiene Engineer for the Pennsylvania Manufacturers Association Casualty Insurance Company, Finance Building, South Penn Square. He was formerly Assistant Director of the Bureau of Industrial Hygiene, State Department of Health, Commonwealth of Pennsylvania.

LIEUTENANT COLONEL LEE B. GRANT, former Chief, Industrial Hygiene and Safety Branch, Preventive Medicine Division, Eighth Army, Far East Command, has been named deputy commander of the Army Environmental Health Laboratory and chief of the Occupational Health Division at the Army Chemical Center.

A native of Michigan, COLONEL GRANT was graduated from the University of Louisville in 1945 with a Doctor of Medicine degree. After completing a year's internship at Henry Ford Hospital, he entered the Army as a physician. He attended the University of Cincinnati under the Army Medical Department Civilian Residency Program and received a degree of Doctor of Science, Industrial Medicine in 1952. COLONEL GRANT is a member of the American Medical Association, Industrial Medical Association and the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION.

✦ *Obituaries*

CARL PETERSON, M.D., Secretary of the Council on Industrial Health of the American Medical Association, died on September 27 following an airplane crash near Asheville, North Carolina.

DR. PETERSON was born in Rockford, Illinois on December 6, 1899. He attended Augustana College and the University of Minnesota Medical School attaining his M.D. in 1927. In 1937 the AMA Council on Industrial Health was established and he was made its Secretary, a position he held at the time of his death. DR. PETERSON was a member of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION and the American Medical Association. He was a Fellow of the American Public Health Association, American Academy of Occupational Medicine, American Academy of Compensation Medicine and the Industrial Medical Association. He served on as many as 20 committees, both medical and industrial.

No finer eulogy could be rendered DR. PETERSON than that given by his pastor: "The last chapter in the life of DR. CARL is not being written today. The work he did with quiet competence in his chosen field all these years will go on—with a better standard of living and health for many people who have never heard his name."

THOMAS NASH WHITE, Health Physicist at the Los Alamos Scientific Laboratory, died suddenly at his home in Santa Fe, New Mexico, on September 16, 1955. DR. WHITE was born August 16, 1903, in New Bedford, Massachusetts, receiving his B.S. and Ph.D. in Physics from McGill University in 1926 and 1929, respectively. After two years spent at the Rockefeller Institute for Medical Research and the California Institute of Technology, DR. WHITE spent the period from 1932 to 1942 with the U. S. Public Health Service engaged in the development of x-ray equipment for biomedical research. He subsequently spent the period from 1942 to 1946 with the National Bureau of Standards, and in the following year did research on survival problems in the Arctic for the Strategic Air Command.

DR. WHITE joined the staff of the Los Alamos Scientific Laboratory in 1947, rapidly becoming leader of the Radiological Physics Group. In

this field he was responsible for all health physics work at Los Alamos and, in addition, served as a member of the Radiological Safety Group and as Advisor to the Test Director at all weapon tests in Nevada and at the Pacific Proving Ground since 1951. In recent years, DR. WHITE was engaged principally in research on developing new methods of forecasting fallout following atomic and hydrogen bomb detonations.

DR. WHITE is survived by his wife and two daughters. He was a member of the American Physical Society, Radiation Research Society, and of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION. He was the Program Arranger for the Radiation Section at the annual meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION in the spring of 1955.

J. H. HOLDEN, Chief Chemist at the Pittsburgh Testing Laboratory, died October 2, 1955. Born in Amherst, Massachusetts, the son of a minister, MR. HOLDEN received his elementary and high school education there; he attended Roxbury Latin School and entered Tufts College at Medford, Massachusetts, in 1912. After two years study at Tufts, MR. HOLDEN resumed his study at the University of Kansas, where he was awarded his degree in Chemical Engineering in 1917.

He served as a Sergeant in the Chemical Warfare Service during World War I. At the completion of his army career, MR. HOLDEN was employed with Tulsa Laboratories for a couple of years before returning to Massachusetts for graduate study at Massachusetts Institute of Technology. He joined the Pittsburgh Testing Laboratory in 1923. Mr. W. F. Walters, who has been assistant to MR. HOLDEN for two years is assuming the duties of industrial hygiene with Pittsburgh Testing Laboratory. MR. HOLDEN was Secretary-Treasurer of the Pittsburgh section of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION in 1947 and President in 1949.

Index to Volume 16

Subject and author entries are made for all technical articles. Obituaries are indexed under this heading.

A

Abstracts, From Foreign Exchange Journals, Mar. p. 77, June, p. 152, Sep. p. 244, Dec. p. 338
Acetaldehyde, Hygienic Guide, Sep. p. 237
Air Pollution:
- A Method for Determining Sources of Particulate Atmospheric Carbon, Dec. p. 293
- Air Pollution—Some Epidemiologic Aspects, Sep. p. 198
- Atmospheric Pollution Study of a Non-Industrial Area, June, p. 141
- Basic Problems in the Detection of Microbiological Air Pollution, June, p. 113
- Pitfalls in Using Maximum Allowable Concentrations in Air Pollution, Sep. p. 230

Alpha Hazard Monitoring Instruments, Mar. p. 60
Amyl Acetate, Hygienic Guide, Sep. p. 241
Aniline, Hygienic Guide, Dec. p. 331
Arnold, James: A Method for Determining Sources of Particulate Atmospheric Carbon, Dec. p. 293
Atchley, R. W.: The Toxicity of the Products Formed by the Thermal Decomposition of Certain Organic Substances, Sep. p. 187

B

Benzol, Hygienic Guide, Dec. p. 333
Blatz, Hanson: Potential Radiation Hazards in the Use of X-ray Diffraction Equipment, June, p. 108
Bloomfield, Bernard, D.: Atmospheric Pollution Study of a Non-Industrial Area, June, p. 141
Bloomfield, John J.: Training Industrial Hygiene Chemists in Latin America, Mar. p. 64
Book Reviews:
- Dust is Dangerous, By C. N. Davies, Sep. p. 244
- Industrial Dust, Second Edition, By Philip Drinker and Theodore Hatch, Mar. p. 77

Butyl Alcohol, Hygienic Guide, Sep. p. 240

C

Cadmium, Hygienic Guide, Sep. p.238
Campbell, Evan E.: The Determination of Mercury in Urine, Dec. p. 275
Cappel, J. W.: The Toxicity of the Products Formed by the Thermal Decomposition of Certain Organic Substances, Sep. p. 187
Carbon Monoxide Concentrations—A Comparison of Detroit and Los Angeles, Sep. p. 225
Carbon Tetrachloride, Hygienic Guide, Sep. p. 239
Castrop, V. J.: A Comparison of Carbon Monoxide Concentrations in Detroit and Los Angeles, Sep. p. 225
Chapman, Harlow: Dust Counting Reliability, Sep. p. 201
Clayton, George: A Method for Determining Sources of Particulate Atmospheric Carbon, Dec. p. 293
Cleveland, F. P.: The Toxicity of the Products Formed by the Thermal Decomposition of Certain Organic Substances, Sep. p. 187
Coleman, Allan L.: Threshold Limits —A Panel Discussion, Organic Vapors, Mar. p. 28
Collection Efficiency of Air Cleaning and Air Sampling Filter Media, June, p. 123
Comparative Toxicity of Boranes, Dec. p. 280
Constant Flow Suction Unit for Aerosol Sampling Work, June, p. 134
Control of Occupational Health Hazards—Concepts of Engineering Application, June, p. 131
Cope, R. W.: Determination of Small Quantities of Isophorone in Air, Mar. p. 55
Czerwonka, Lawrence J.: Sampling and Analysis of Industrial Process Dust, Dec. p. 283

D

Denham, R. T.: The Toxicity of the Products Formed by the Thermal Decomposition of Certain Organic Substances, Sep. p. 187
Determination of Acrolein in the Presence of Other Aldehydes, Sep. p. 221
Determination of Ethylene Oxide in Air—Experience in the Use of Lubatti's Method, Mar. p. 52
Determination of Fluoride in Urine, Sep. p. 215
Determination of Mercury in Urine, Dec. p. 275
Detwiler, C. G.: Collection Efficiency of Air Cleaning and Air Sampling Filter Media, June, p. 123
Dust Counting Reliability, Sep. p. 201

F

Fanney, Julius: A Unique Wet Collector for Lightweight Aggregate Dusts, Dec. p. 301

Fitzgerald, J. J.: Collection Efficiency of Air Cleaning and Air Sampling Filter Media, June, p. 123
Formaldehyde, Hygienic Guide, Dec. p. 336

G

Gafafer, W. M., D. Sc.: Air Pollution—Some Epidemiologic Aspects, Sep. p. 198
Gardner, Dwight E.: The Determination of Fluoride in Urine, Sep. p. 215
Glorig, Aram, M. D.: The Industrial Hygienist and Ear Protection, Mar. p. 40
Goetz, Alexander, Ph. D.: Basic Problems in the Detection of Microbiological Air Pollution, June, p. 113
Graul, Robert J.: The Determination of Acrolein in the Presence of Other Aldehydes, Sep. p. 221

H

Hatch, Theodore, Threshold Limits—A Panel Discussion, Permissible Dustiness, Mar. p. 30
Head, Billye Marie: The Determination of Mercury in Urine, Dec. p. 275
Hendricks, Van: President's Page, June, p. 151, Sep. p. 243, Dec. p. 330
Holaday, Duncan, A.: Alpha Hazard Monitoring Instruments, Mar. p. 60
Hollingsworth, R. L.: Determination of Ethylene Oxide in Air-Experience in the Use of Lubatti's Method, Mar. p. 52
Hydrogen Sulfide, Hygienic Guide, Dec. p. 335
Hygienic Guide Series:
Acetaldehyde, Sep. p. 237
Amyl Acetate, Sep. p. 241
Aniline, Dec. p. 331
Benzene, Dec. p. 333
Butyl Alcohol, Sep. p. 240
Cadmium, Sep. p. 238
Carbon Tetrachloride, Sep. p. 239
Formaldehyde, Dec. p. 336
Hydrogen Sulfide, Dec. p. 335
Sulfur Dioxide, Dec. p. 332

I

Industrial Dusts—An X-ray Diffraction Method for Determination of Origin, Mar. p. 68
Industrial Hygiene Program—For a Benzene Extraction Plant in a Petroleum Refinery, Mar. p. 46
Isophorone, Determination of Small Quantities in Air, Mar. p. 55

K

Kacy, H. W., Jr.: Determination of Small Quantities of Isophorone in Air, Mar. p. 55
Kumler, Kay: A Rapid Method for the Spectrochemical Analysis of Lead in Blood, Dec. p. 296

L

Landry, A. S.: Training Industrial Hygiene Chemists in Latin America, Mar. p. 64
Larson, E. E.: The Toxicity of the Products Formed by the Thermal Decomposition of Certain Organic Substances, Sep. p. 187
Levinskas, George, J., Ph. D.: Comparative Toxicity of Boranes, Dec. p. 280

M

Mallette, Fred: Problems in the Skin Testing of Industrial Compounds—Development of Polyvalent Sensitivity, Dec. p. 324
McAlduff, H. J.: The Sale of Uranium-Contaminated Scrap Carbon Steel to Commercial Channels, Mar. p. 73
McLaughlin, J. E., Jr.: Potential Radiation Hazards in the Use of X-ray Diffraction Equipment, June, p. 108
Meyer, Alvin F., Jr., Lt. Col., USAF, (MSC):
Emergency Radiation Exposure Control—Development of Criteria, Sep. p. 210
The Control of Occupational Health Hazards—Concepts of Engineering Application, June p. 131
Morgan, Karl, Ph. D.: Problems Associated With the Application of External and Internal Radiation Exposure Limits, Dec. p. 307
Motor-Driven Syringes for Micro-Metering of Gases, June, p. 121

O

Obituaries:
Herndon, Henry Taylor, Sep. p. 245
Holden, J. H., Dec. p. 340
Peterson, Carl, M. D., Dec. p. 340
White, Thomas Nash, Dec. p. 340

P

Patty, Frank A.:
A Comparison of Carbon Monoxide Concentrations in Detroit and Los Angeles, Sep. p. 225
A Method for Determining Sources of Particulate Atmospheric Carbon, Dec. p. 293

R

Radiation:
Emergency Radiation Exposure Control—Development of Criteria. Sep. p. 210
Potential Radiation Hazards in the Use of X-ray Diffraction Equipment, June, p. 108
Problems Associated With the Application of External and Internal Radiation Exposure Limits, Dec. p. 307
Rapid Method for the Spectrochemical Analysis of Lead in Blood, Dec. p. 296
Roberts, Wesley J.: The Determination of Acrolein in the Presence of Other Aldehydes, Sep. p. 221
Ruhf, Russell: Dust Counting Reliability, Sep. p. 201

S

Saltzman, Bernard E.: Motor-Driven Syringes for Micro-Metering of Gases, June, p. 121
Sampling and Analysis of Industrial Process Dust, Dec. p. 283
Schmelzer, Lawrence L.: The Origin of Industrial Dusts—An X-ray Diffraction Method for Determination, Mar. p. 68
Schmidt, A. C.: A Constant Flow Suction Unit for Aerosol Sampling Work, June, p. 134
Schreiber, Thomas: A Rapid Method for the Spectrochemical Analysis of Lead in Blood, Dec. p. 296
Schrenck, J. H.: Pitfalls in Using Maximum Allowable Concentrations in Air Pollution, Sep. p. 230
Seifert, Harry: A Unique Wet Collector for Lightweight Aggregate Dusts, Dec. p. 301
Smith, Frank A.; Ph. D.: The Determination of Fluoride in Urine, Sep. p. 215
Stephens, J. F.: A Comparison of Carbon Monoxide Concentrations in Detroit and Los Angeles, Sep. p. 225
Sterner, James H., M. D.:
The Experimental Animal-Man-in Industrial Hygiene, June, p. 103
Threshold Limits—A Panel Discussion, Moderator, Mar. p. 27
Stokinger, H. E., Ph. D.: Threshold Limits—A Panel Discussion, Gases, Mar. p. 35
Sulfur Dioxide, Hygienic Guide, Dec. p. 332

T

The Experimental Animal-Man-in Industrial Hygiene, June p. 103
Threshold Limits—A Panel Discussion, Mar. p. 27
Toxicity of the Products Formed by the Thermal Decomposition of Certain Organic Substances, Sep. p. 187
Training Industrial Hygiene Chemists in Latin America, Mar. p. 64
Treon, J. F.: The Toxicity of the Products Formed by the Thermal Decomposition of Certain Organic Substances, Sep. p. 187

U

Unique Wet Collector for Lightweight Aggregate Dusts, Dec. p. 301
Uranium-Contaminated Scrap Carbon Steel, Sale of, to Commercial Channels, Mar. p. 73

V

Van Sandt, Walter A.: The Determination of Acrolein in the Presence of Other Aldehydes, Sep. p. 221
Venable, Fred S.: An Industrial Hygiene Program—For a Benzene Extraction Plant in a Petroleum Refinery, Mar. p. 46
von Haam, E.: Problems in the Skin Testing of Industrial Compounds—Development of Polyvalent Sensitivity, Dec. p. 324

W

Waling, B. F.: Determination of Ethylene Oxide in Air—Experience in the Use of Lubatti's Method, Mar. p. 53
Walworth, H. T.: President's Page, Mar. p. 76
Weber, Herbert J.: Threshold Limits—A Panel Discussion, Metal Fumes, Mar. p. 38
Westlin, Karl: Sampling and Analysis of Industrial Process Dust, Dec. p. 283
Wheeler, D. E., Ph. D.: The Industrial Hygienist and Ear Protection, Mar. p. 40
Wiltshire, L. L.: A Constant Flow Suction Unit for Aerosol Sampling Work, June p. 134

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION
Officers, 1955-56

N. V. HENDRICKS ..... President
Esso Research and Engineering Company
P.O. Box 51, Linden, New Jersey.

LESTER V. CRALLEY, PH.D. ..... President-Elect
Aluminum Company of America
1501 Alcoa Building, Pittsburgh 19, Pennsylvania

HERBERT T. WALWORTH ..... Past-President
Lumbermens Mutual Casualty Company
4750 Sheridan Road, Chicago 40, Illinois

NORTON NELSON, PH.D. ..... Secretary
New York University Medical Center
550 First Avenue, New York 16, New York

JOSEPH F. TREON, PH.D. ..... Treasurer
Kettering Laboratory, Cincinnati, Ohio

GEORGE D. CLAYTON ..... Executive-Secretary
14125 Prevost, Detroit 27, Michigan

Board of Directors

VINCENT J. CASTROP
General Motors Corporation

G. H. COLLINGS, JR., M.D.
Tennessee Valley Authority

ROBERT E. ECKARDT, M.D.
Standard Oil Development Company

MERRIL EISENBUD
U.S. Atomic Energy Commission

E. C. HYATT
Los Alamos Scientific Laboratory

FREDERICK S. MALLETTE
American Society of Mechanical Engineers

WILLIAM T. MCCORMICK
Inland Steel Company

K. W. NELSON
American Smelting & Refining Company

HENRY F. SMYTH, JR., PH.D.
Mellon Institute

HERBERT E. STOKINGER, PH.D.
Division of Occupational Health, U.S.P.H.S.

ELMER P. WHEELER
Monsanto Chemical Company

American Industrial Hygiene Association Quarterly

HOWARD N. SCHULZ ..... Editor
Abbott Laboratories
North Chicago, Illinois

HERBERT J. WEBER ..... Advisory Editor
American Foundrymen's Society
Chicago, Illinois

LLOYD E. GORDON ..... Associate Editor
Zurich-American Insurance Companies
135 South LaSalle Street, Chicago 3, Illinois

CHARLES WYMAN ..... Circulation Editor
Western Electric Company
Chicago 23, Illinois

JAMES A. MARTIN ..... Advertising Editor
General Electric Company
Cincinnati 15, Ohio

WILLIAM G. FREDRICK, Sc.D. ..... Associate Advertising Editor
Detroit Department of Health
Detroit, Michigan

FRED R. INGRAM ..... Associate Advertising Editor
University of California
Berkeley 4, California

WILLIAM S. JOHNSON ..... Associate Advertising Editor
Bethlehem Steel Company
Bethlehem, Pennsylvania

JOHN M. KANE ..... Associate Advertising Editor
American Air Filter Company
Louisville, Kentucky

KENNETH W. NELSON ..... Associate Advertising Editor
American Smelting & Refining Company
Salt Lake City, Utah

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION COMMITTEES

Auditing Committee

D. J. Lauer, M.D., Chairman; J. F. Morgan; Thomas Bonney.

Awards Committee

J. W. Hammond, Chairman; Warren A. Cook; Lester V. Cralley, Ph.D.

Conference Committee

Allen D. Brandt, Sc.D., Chairman; Eldred C. Brainerd; Elmer P. Wheeler; William E. Shoemaker.

Arrangements:
Frank J. Willard, Chairman; Herbert I. Miller; Victor H. Kindsvatter, Ph.D.; J. W. Miller; Louis F. Weller; Raymond Smith.

Banquet:
William M. Pallies, Chairman; Louis F. Weller; Bayard R. Brick, Ph.D.

Entertainment:
J. S. Sharrah, Chairman; J. A. Calhoun, M.D.; Dorothy B. Hood; Richard A. Sutter, M.D.

Field Trips:
William H. Krecker, Chairman; Louis F. Garber; William H. Wiswesser; Vaughn H. Hill.

Scientific Exhibits:
G. M. Glidden, Chairman; A. C. Pabst; J. H. Rook.

Development Committee

Frank A. Patty, Chairman; W. G. Hazard; J. C. Radcliffe; John C. Soet; Joseph F. Treon, Ph.D.; Arthur J. Vorwald, M.D.; Lt. Commander T. E. Shea.

Editorial Committee

Jack C. Radcliffe, Chairman; Manfred Bowditch; Philip Drinker, Sc.D.; James H. Sterner, M.D.; Elda E. Anderson, M.D.

Education Committee

Norton Nelson, Ph.D., Chairman; Rodney R. Beard, M.D.; Leslie Silverman, Sc.D.; Bernard D. Tebbens, Sc.D.; Harry F. Schulte.

Committee on Fellowships

William R. Bradley, Chairman; Merril Eisenbud; William T. Ingram; Clyde M. Berry, Ph.D.; E. D. Palmer, Ph.D.; Seward E. Miller, M.D.

Ethics Committee

Karl L. Dunn, Chairman; K. E. Markuson, M.D.; Joseph F. Mellor; Robley Evans, Ph.D.

Legal Committee

Vincent J. Castrop, Chairman; Saul J. Harris; Harry E. Seifert; John M. Kane; Paul W. McDaniel; Henry F. Smyth, Ph.D.

Local Sections Committee

Edwin C. Hyatt, Chairman; Paul Lange; Lester M. Petrie, M.D.; Melvin W. First, Sc.D.; James H. Holden; Carl U. Dernehl, M.D.

Membership Committee

Charles R. Williams, Ph.D., Chairman; Henry G. Lamb; C. Richard Walmer, M.D.; G. Victor Beard; Bernard D. Bloomfield; J. C. Hart.

Nominating Committee

Herbert T. Walworth, Chairman; Allen D. Brandt, Sc.D.; Henry F. Smith, Ph.D.

Program Committee

Lester V. Cralley, Ph.D., Chairman; W. C. L. Hemeon; Anna M. Baetjer, Sc.D.; J. Brennan Gisclard; John Ege; Christine Einert, M.D.; T. J. Burnett; J. F. Mellor, Jr.; K. M. Morse; V. K. Rowe; A. C. Stern.

Publicity Committee

William E. Shoemaker, Jr., Chairman; Harry E. Tebrock, M.D.; Paul E. Morrow; George C. Stoecker.

Standards Committee

Carlton E. Brown, ScD., Chairman; Edgar C. Barnes; W. E. McCormick; Arthur C. Stern; Karl Z. Morgan, Ph.D.

Tellers Committee

W. E. Kohn, Chairman; Paul E. Toth.

Representative to Council of American Association for the Advancement of Science: Lester M. Petrie, M.D.

Representative to Inter-Society Committee on Laboratory Services Related to Health: Henry F. Smyth, Ph.D.

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION
Technical Committees

Coordinator of Technical Committees: H. T. Walworth.

Air Pollution Committee

George Clayton, Chairman; Harlow Chapman; Leonard Greenburg, M.D.; Jack C. Radcliffe; J. S. Sharrah; Lewis J. Cralley, Ph.D.; Paul M. Giever.

Analytical Chemistry Committee

J. Brennan Gisclard, Chairman; Frederick H. Goldman, Ph.D.; Kathleen Kumler; Elgin D. Sallee; Alfred N. Setterlind; Ralph G. Smith, Ph.D.

Engineering Committee

Kenneth E. Robinson, Chairman; Floyd Calhoun; L. G. Miller; W. H. Williamson; Melvin W. First, Sc.D.; Joseph A. Houghton; Alfredo Salazar; James Barrett; Paul Lange; W. G. Hazard; R. J Beaman; Theodore Hatch; George Reichenbach, Jr.; Constantin Yaglou; F. W. Church.

Noise Committee

Kenneth M. Morse, Chairman; Allen D. Brandt, Sc.D.; Jerome R. Cox, Sc.D.; Leo G. Doerfler, M.D.; Frank Patty; George L. Bonvallet; Kenneth C. Stewart; Paul J. Whitaker, M.D.; Lester V. Cralley, Ph.D.; Vaughan H. Hill; Paul Michael; George M. Wilkening.

Hygienic Guides Committee

William E. McCormick, Chairman; Francis F. Heyroth, M.D.; Hervey B. Elkins, Ph.D.; David W. Fassett, M.D.; William B. Harris; Melvin W. First, Sc.D.; H. E. Stokinger, Ph.D.; H. E. Seifert; Clyde M. Berry, Ph.D.

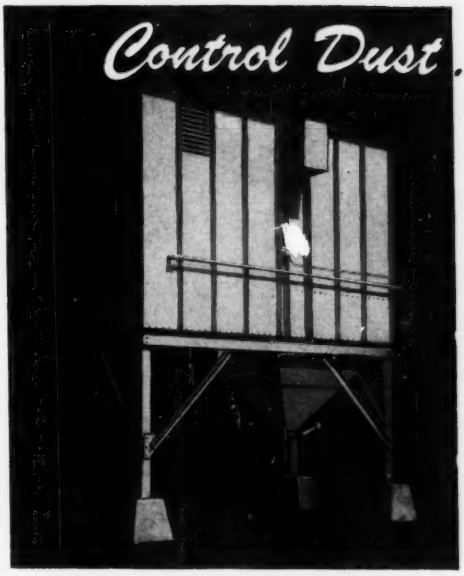
Radiation Committee

Harry F. Schulte, Chairman; John E. Bradley; Thomas J. Burnett; Robert C. Gallagher; John A. Harley; Saul J. Harris; Duncan A. Holaday; Donald E. VanFarowe; Thomas H. White, Ph.D.

Toxicology Committee

H. F. Smyth, Ph.D., Chairman; V. K. Rowe; John A. Zapp, Ph.D.; C. Boyd Shaffer, Ph.D.; C. H. Hine, M.D., Ph.D.; H. W. Gerald, M.D., Ph.D.; Frank Patty.

UNIVERSITY OF MICHIGAN
DEC 21 1955
PUBLIC HEALTH LIBRARY



Control Dust ..with the RUEMELIN TUBULAR TYPE FILTER

Ruemelin Dust Filters achieve a high rate of efficiency in the control of fine dusts. Our tubular bag design provides—

- **Low resistance to air flow.**
- **Thorough shaking of bags while fan is shut down. Eliminates tautness.**
- **Maintenance, inspection and replacement of tubes made easy by our patented design.**

Ruemelin Filters handle dusts created in metal working plants, foundries, cement mills and many similar industrial applications. Sizes from 250 to 30,000 cfm. Over 2000 of our filters in service for the past 25 years. Write for bulletin 24-D.

REMOVE WELDING FUMES *at the Source!*

Welding shops equipped with Ruemelin Fume Collectors are assured of a clean shop atmosphere. Noxious fumes, heat and smoke are eliminated at their source, thus improving working conditions, lessening fatigue and paving the way for increased plant production.

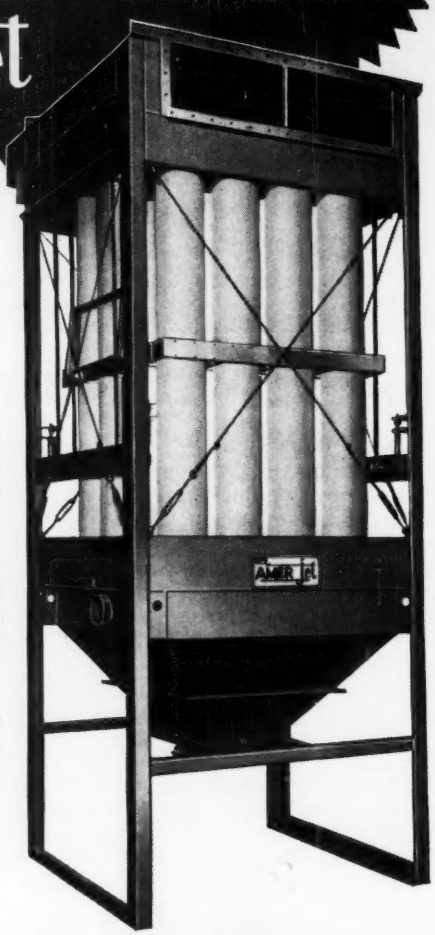
The Ruemelin Fume Collector hood can be instantly moved where needed anywhere in the booth welding area. No tedious adjustments necessary. Just pull the inlet hood to the welding position and you are ready to go. Note the new spring-loaded counterbalance mechanism which makes Fume Collector much easier to handle. Ask for Bulletin 37-E illustrating this new feature.

Ruemelin Fume Collector in operation.

RUEMELIN MFG. CO.,
3902 N. Palmer Street
MILWAUKEE 12, WISCONSIN, U.S.A.
DUST COLLECTING EQUIPMENT • WELDING FUME COLLECTORS

For Extremely Fine Dust or
Dust That Must Be Reclaimed Dry

Add Up The Advantages of AMER Jet



OUTSTANDING PERFORMANCE. Reverse jet principle assures constant air volume by continuous re-conditioning of the cleaning tubes—permits *five times greater* velocities through the cleaning media than ordinary fabric collectors.

LOWER SERVICE COST. Five times greater capacity means 1/5 less media inspection and replacement costs. There are no bulky drape hose connections for high pressure air. Moving shoe takeoff eliminates wear on hose and fabric.

SMALLER SPACE REQUIREMENTS. Compact design and factory assembly permit easy erection of AMERjet on the job at minimum cost. Unit can be located close to dust source, eliminating long duct runs.

AMERjet Fabric Dust Arresters are available for handling any exhaust volume. For complete information, write for Bulletin 279.

AAF herman nelson

American Air Filter
COMPANY, INC.
253 Central Avenue, Louisville 8, Kentucky
American Air Filter of Canada, Ltd., Montreal, P. Q.

ew Type Of Soap That's Almost

TO WASTE!

SBS-60 CREAM DEODORANT SOAP

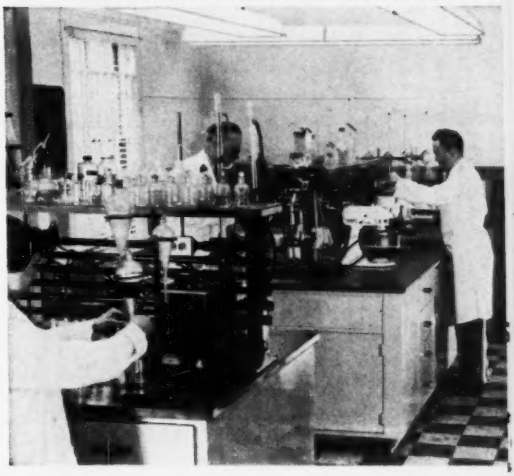
SUCCESSOR TO LIQUID AND BAR SOAPS

senting the first major soap devel-

nent in a quarter of a century . . .

ings on soap costs up to 50% assured

announcement of SBS-60 Cream Deodorant Soap
and for all solves the problem of costly waste in the
of liquid and bar soaps. Today for the first time,
vailability of SBS-60 Cream Deodorant Soap brings
y soap waste to an end for your company. Three
s of extensive laboratory testing and country-wide
tests have proved the value of SBS-60. Savings up
0% in soap costs are matters of record . . . an end
ostly soap dispensing problems is assured . . . im-
ement in employee morale is another handsome
end when SBS-60 is used. Special announcement
ture has been prepared to answer all your ques-
. . . this information is valuable to you and your
pany—send for it now.



MODERN LABORATORY EQUIPMENT in the hands of skille
chemists produced this first major soap development i
lecades . . . SBS-60 Cream Deodorant Soap. Thei
assignment was to come up with a product that woul
eliminate the wastes of present day liquid and ba
soaps . . . their success is now a matter of recorded fac

SEND FOR YOUR COPY OF THIS

SPECIAL ANNOUNCEMENT LITERATURE

SUGAR BEET PRODUCTS COMPANY, 302 WALLER ST., SAGINAW 45, MICH.

Gentlemen: Rush me the special announcement literature on the new SBS-60 Cream Deodorant Soap.

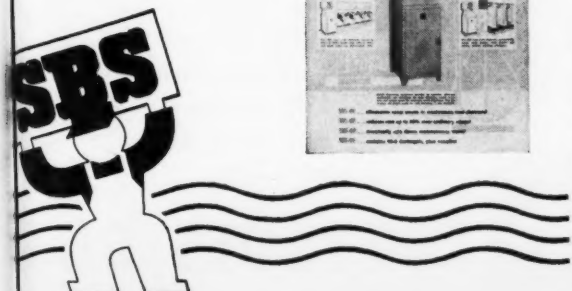
NAME _____

TITLE _____

COMPANY _____

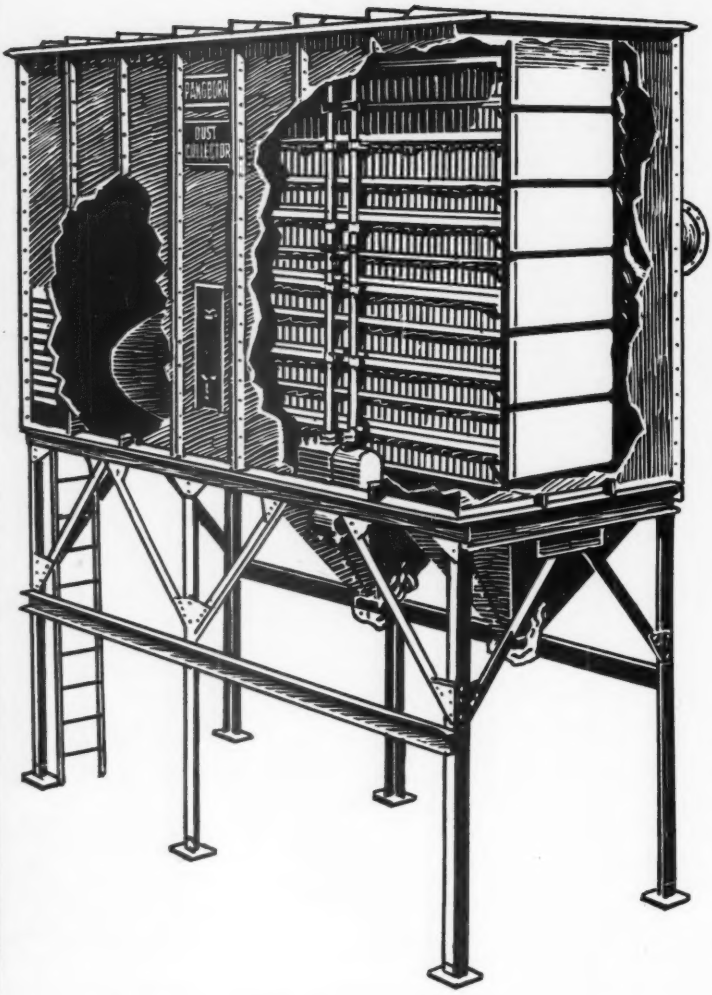
ADDRESS _____

CITY _____ ZONE ____ STATE _____



ugar Beet Products Co.
mical By-Products Division
Waller St., Saginaw , Mich.

Canadian Subsidiary
Chemical By-Products, Ltd.
8 Ripley Ave., Toronto 3, Canada



High efficiency assured

Pangborn Dust Collectors assure high efficiency recovery of fine dusts. The cutaway view above shows *cloth filter* arrangement in a Pangborn "CH" Collector. Note how maximum filtering area is contained in a compact case. Filter life is prolonged because dust laden air passes through Collector at *low velocity* and positive dust removal is assured; exhausted air is so clean it can often be returned direct to plant!

$ $ $

It pays to keep your plant DUST-FREE!

Uncontrolled dust can be a dangerous and costly member of your production team! It injures employee health and morale, hampers production, increases plant housekeeping and machinery maintenance costs, endangers public relations and is often responsible for the loss of valuable, salvageable material.

Pangborn Dust Control puts a stop to that! Investigate Pangborn Dry and Wet Dust Collectors and see how they can save you time, trouble and money. There are sizes and types for every need. Write today for free bulletin, "Out of the Realm of Dust" to: PANGBORN CORP., 4500 Pangborn Blvd., Hagerstown, Md.

Pangborn CONTROLS DUST

Winner and New Champion

FINE ORGANICS'

F.O. 128

"Safe-Tee" Solvent

SAFETY ENGINEERS, PLANT MAINTENANCE SUPERVISORS and INDUSTRIAL HYGIENIS with leading industrial organizations easily prove F.O. 128 superiority!

1. ***SAFETY ENGINEERS impressed by High Flash Point of F.O. 128.*** This important feat of FINE ORGANICS' improved Safe-Tee Solvent reduces Fire Hazards, increases efficie and raises personnel morale. Wherever Fire Hazards prevail the importance of us F.O. 128 is imperative!

2. ***INDUSTRIAL HYGIENISTS widely recommend F.O. 128.*** Exhaustive "in-plant" t establish F.O. 128 as the efficient replacement for Carbon Tetrachloride. The LOW toxi of F.O. 128 is an invaluable aid in avoiding harmful effects on plant personnel. Substitut of F.O. 128 in your cleaning operations reduces and eliminates health hazards norm associated with ordinary solvents.

3. ***PLANT ENGINEERS and MAINTENANCE SUPERVISORS appreciate the versatility F.O. 128.*** "On-the-job" results prove F.O. 128 fills the bill for a faster, non-corro cleaning-degreasing solvent. Safe-Tee Solvent is ideal for heavy work but will not dam finely machined surfaces, or attack insulation. Maintenance Supervisors use F.O. 128 effective cleaning and degreasing of Electric Motors, Power Generators, Condens Starters, Contact Points, Production Equipment and ALL areas in plants where greasy, dirt must be removed. F.O. 128 may be used in process cleaning for pre-paint or pre-pl operations. No significant residue on drying.

Let F.O. 128 go to work for you. Watch this improved FINE ORGANICS' cleaning and degrea solvent "knock-out" oily dirt and grease ***FASTER . . . MORE EFFICIENTLY . . . SAFER!***

Write Dept. IH for additional information regarding F.O. 128 and other FINE ORGANICS' S Tee Solvents and the name of your nearest FINE ORGANICS' representative.

Ask for F.O. Technical Bulletin "How to Clean Electric Motors."

FINE ORGANICS, Inc. 211 EAST 19th STREET • NEW YORK 3, N

VI-LAN CLEAN

dispensers

on the job and in wash rooms will prevent the menace of

dermatitis

. . . lost man hours and lost profits!

This new antiseptic all-purpose skin cleanser contains ACTAMER, a non-toxic bacteriostat, perfected by Monsanto Chemical Company, exerting a powerful inhibitory action against harmful skin bacteria for 48 hours after use.

VI-LAN CLEAN does what ordinary soaps can not do. It removes greases, oils, paint, acids, graphites, printing inks, asphalt, rubber, gasket cements and other industrial soils and sediments, and provides the prophylaxis inhibiting the germs which too often put employees out of commission.

So, serve and protect your employees with VI-LAN CLEAN—install the new VI-LAN CLEAN dispensers in every wash room and on critical on-the-job locations. MAY BE USED WITH OR WITHOUT WATER.

To fill dispensers VI-LAN CLEAN is packed in polyethylene bags, allowing you to release any amount of the cream simply by finger pressure on the bag without waste. This container also may be used conveniently as a portable dispenser on trucks and outside jobs.

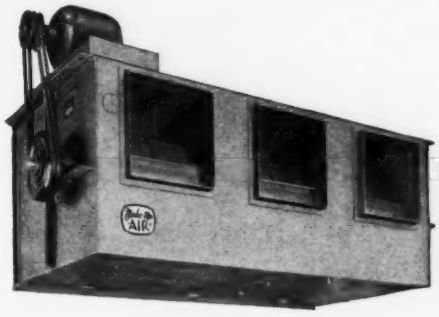
Also available in convenient pint, quart and gallon containers for home and shop use.

Write for descriptive folder today!

DAMERON
enterprises, inc.
427 So. 20th Street
Louisville 3, Kentucky

CORRECT AIR STARVATION
AND BALANCE MINUS PRESSURE
WITH *nyb* Make-Up AIR

to safeguard health, bring comfort to workers, reduce absenteeism and increase efficiency.



Where gases, dust and fumes are removed in large volume with exhaust fans, depleting the air supply within the building, and creating a minus pressure, we recommend the installation of our Make-Up Air units.

These simple, compact, ceiling suspended units replace the air from the outside, in an even and constant flow, without drafts or noise; warmed, cleaned and delivered in definite known quantities to balance the known loss. Correct drafty conditions and uncontrolled infiltration. Furnished in 4 sizes from 5,000 cfm to 20,000 cfm.

Write for Bulletin 523.

New York Blower products are skillfully engineered, accurately rated, have a nation-wide reputation for dependable performance. They are laboratory tested and fully guaranteed in strict accordance with Standard Test Codes.

CERTIFIED RATINGS
AUTHORIZED BY
N A F M

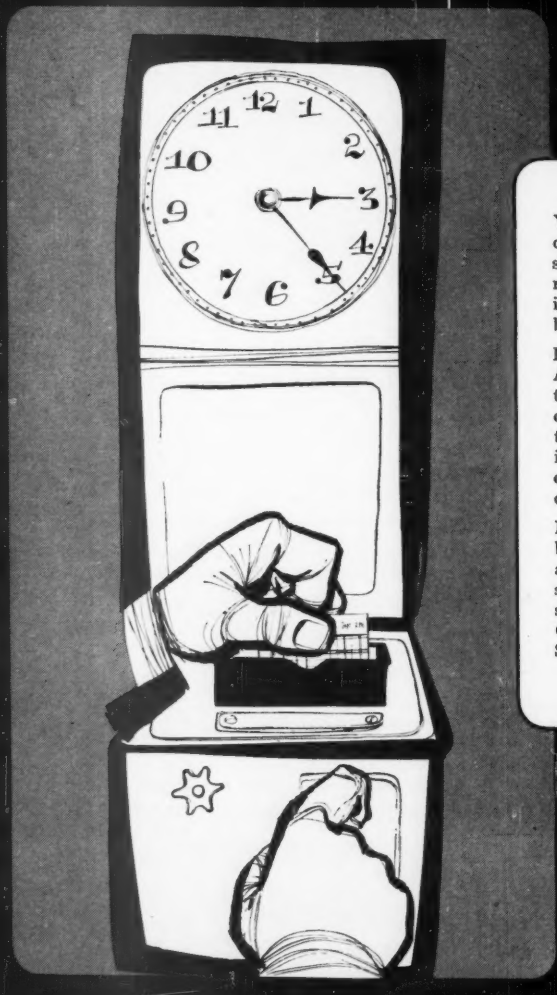
nyb **THE NEW YORK BLOWER COMPANY**

SALES OFFICES • 3145 SOUTH SHIELDS AVENUE • CHICAGO 16

FACTORY, LAPORTE, INDIANA

ACTAMER:

Remarkable New Soap Antiseptic Helps Reduce Absenteeism . . . Cuts Skin Bacteria 97%



You can help keep plant employes on the job by helping them reduce skin disorders. How? Keep washrooms supplied with soap containing ACTAMER, Monsanto's new bacteriostat.

Regular use of soap containing Actamer reduces resident skin bacteria by as much as 97%, thus cutting the chances of skin infections. Control of skin bacteria is important because 60% of all occupational disease compensation cases are based on skin disorders.

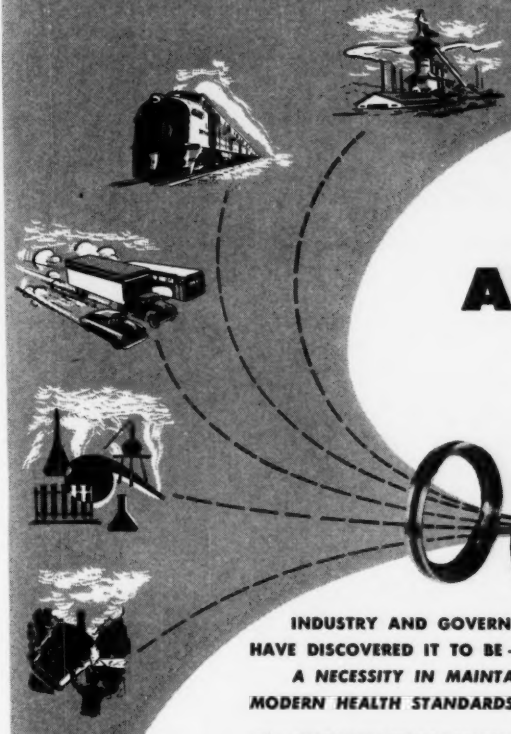
Industrial soaps with Actamer—bar, liquid or powder—are now available. Write us for a list of suppliers. Organic Chemicals Division, MONSANTO CHEMICAL COMPANY, P. O. Box 4788-3 St. Louis 1, Missouri.

Actamer: Reg. U. S. Pat. Off.

MONSANTO
CHEMICALS and PLASTICS
®

SERVING INDUSTRY, WHICH SERVES MANKIND

TO COMBAT AIR POLLUTION . . .



Staplex
TRADE MARK

HI-VOLUME AIR SAMPLER

INDUSTRY AND GOVERNMENT
HAVE DISCOVERED IT TO BE —
A NECESSITY IN MAINTAINING
MODERN HEALTH STANDARDS

The STAPLEX HI-VOLUME AIR SAMPLER has proven to be a basic instrument in combating and controlling air pollution. Time-tested . . . excellent for both indoor and outdoor sampling . . . this sampler accomplishes in 10 minutes what previous units required 36 hours to do.

Originally designed in the Atomic Energy Commission, (N. Y. office), the STAPLEX HI-VOLUME AIR SAMPLER's prime purpose is for accurately sampling large volumes of air for particulate matter by means of filter papers. *It accurately samples air containing particles as small as 1/100th of a micron in diameter.*

Hundreds now in use by Industry and all types of government health agencies, Municipalities, Insurance Companies, etc. to accurately measure factory health hazards, atmospheric conditions, smoke abatement, smog, for mine inspections, and many other applications.

write for details

THE Staplex COMPANY
AIR SAMPLER DIVISION
777-A Fifth Avenue, Brooklyn 32, N.Y.

NAME .....
COMPANY .....
ADDRESS 12-55

WHAT SPENCER *Vacuum* DOES:

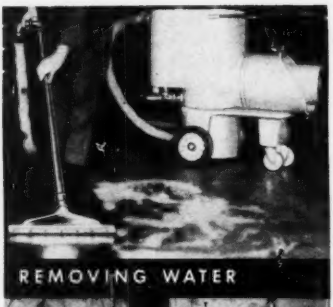
This is a diagram of the Spencer Stationary Vacuum System, with vacuum pipes extending to all parts of the plant. Special vacuum tools, automatic dumping equipment, conveying hot materials and a hundred other developments provide for individual conditions.

Spencer Vacuum is the modern tool of many uses in industry. First; housekeeping and sanitation—faster, better and at lower cost.

Second; big advances have been made in applying vacuum to the production line —reclaiming automatically, conveying raw and waste materials by the ton and doing a hundred jobs which are not practical by hand or any other method. Spencer offers the most complete line in both the stationary installed type and heavy duty portable machines.

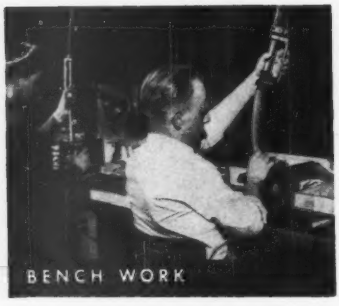
For data on types of equipment and tools, selection charts and illustrations of special applications, ask for the new Bulletin No. 155.

The Spencer Turbine Company
Hartford, Connecticut



REMOVING WATER

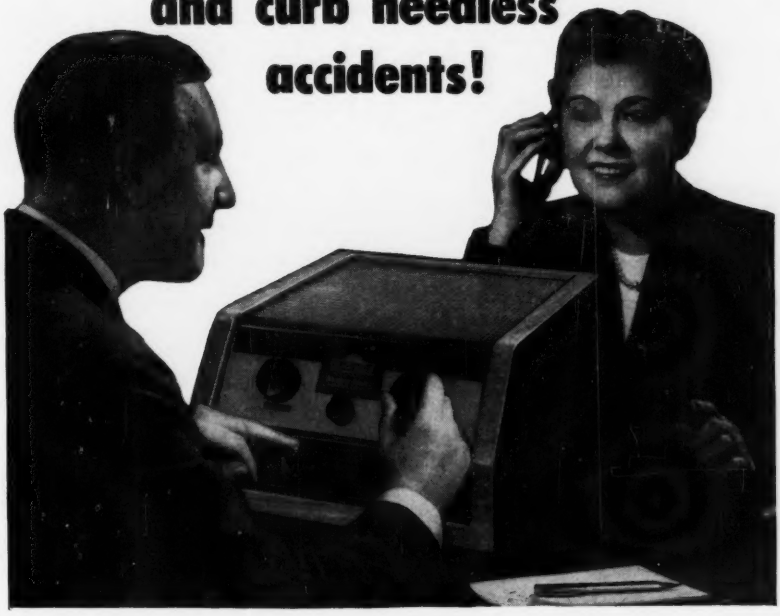
CLEANING FLOORS



BENCH WORK

THE SPENCER TURBINE COMPANY
HARTFORD 6, CONN.

How to protect YOUR company from costly DEAFNESS CLAIMS and curb needless accidents!



Now you can end the possible expense and trouble of future deafness claims — curtail needless accidents — boost plant efficiency, too!

Now science offers you an accurate electronic tool to measure hearing power — the superb *Audiometer by Audivox,* successor to Western Electric Hearing Aid Division, *pioneers with Bell Telephone Laboratories in the development and manufacture of audiometers*!

This invaluable, yet *inexpensive* "hearing yardstick" enables you to make a reliable *pre-employment record* of prior hearing loss . . . then lets you check *post-employment losses* in routine examinations.

The Audivox Audiometer makes it possible to place partly deafened persons in the jobs for which they are best qualified . . . curbs accidents and ups efficiency through swift detection of *any* hearing loss!

You owe it to your company to get all the facts about Audiometers by Audivox.

audivox

SUCCESSOR TO *Western Electric* HEARING AID DIVISION

Dept. H, 123 Worcester St.
Boston 18, Massachusetts

Please send me FREE detailed information on Audiometers by Audivox.

NAME.....

STREET.....

CITY.....STATE.....

THE SKIN CONDITIONING ACTION OF **PAX-LANO-SAV® HEAVY DUTY** GRANULATED SKIN CLEANSER MAKES WORKERS HANDS SMOOTHER, SOFTER AND EASIER TO CLEAN . . . PROGRESSIVELY DAY AFTER DAY UNTIL THEY ARE IN REALLY GOOD WORK-USE CONDITION

THIS IS THE REASON WHY, OVER A PERIOD OF TIME, IT TAKES LESS AND LESS SKIN CLEANSER TO CLEAN DIRTY HANDS. THIS IS JUST ONE OF THE ECONOMIES . . . THROUGH QUALITY . . . THAT MAKES **PAX-LANO-SAV HEAVY DUTY** THE LOWEST COST OF ALL GRANULATED OR POWDERED SKIN CLEANSERS, IN ACTUAL USE.

. . . JUST ONE OF THE REASONS WHY THE USE OF **PAX-LANO-SAV HEAVY DUTY** IN INDUSTRIAL PLANTS FAR EXCEEDS ALL OTHER POWDERED AND GRANULATED SKIN CLEANSERS FOR THE USE OF BOTH MEN AND WOMEN INDUSTRIAL WORKERS. ONCE USED, WORKERS ASK FOR AND DEMAND IT!

RESEARCH - PROGRESS
integrity
PAX
VALUE - SERVICE

LOOK for the PAX ROOSTER

This famous SEAL and Rooster TRADEMARK on each PAX product you purchase is your guarantee that it has been PRE-TESTED and conforms to the PAX deep-rooted rich tradition of RESEARCH and MERIT, assuring you of the greatest degree of PROGRESS, VALUE and SERVICE in every price range.

The PAX reputation for INTEGRITY is backed by over thirty years of pacesetting RESEARCH and MANUFACTURING SKILL.

55-L

OVER 72 MILLION HANDS ARE WASHED EVERY DAY WITH PAX GRANULATED SKIN CLEANSERS

Write Today!

Ask for a side-by-side comparison TEST in your own plant using PAX-LANO-SAV HEAVY DUTY and your present brand of granulated skin cleanser.

Find out why it costs LESS for the very BEST . . . the skin cleanser with the *thirty-year-plus* record of safety.

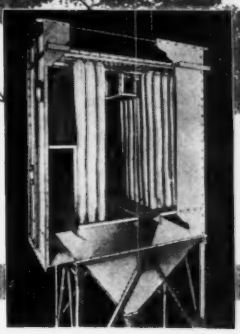
PAX®

G. H. PACKWOOD MANUFACTURING CO.

Manufacturing Chemists

1545 TOWER GROVE AVE. ● ST. LOUIS 10, MO.

10 reasons why DUSTUBE collectors are more efficient and dependable



1. NO COARSE DUSTS REACH THE TUBES. Change of air velocity removes heavier particles first.

2. LOW COST CLOTH TUBES. Light and compact, they are easy to store and economical to ship.

3. SIMPLE INSTALLATION, RAPID TUBE REPLACEMENT. Only one man needed to install tubes.

4. EASY INSPECTION. Condition of cloth tubes readily determined without removing any parts.

5. LONGER CLOTH LIFE. No tension, no abrading metal contact, no coarse dusts to wear the tubes.

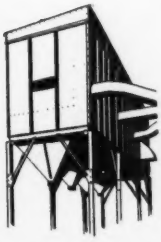
6. BRIDGING AND CLOGGING PREVENTED. Opening into filter tubes is entirely unrestricted.

7. NO FILTER TUBE TENSION. No stretching and subsequent weakening of cloth fibers — longer life.

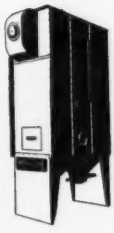
8. LOWER POWER COSTS. Ample expansion areas reduce air velocities and cut power requirements.

9. NO DUST LEAKAGE. Tubes are expanded tightly into cell plate to prevent dust leakage.

10. FAST, THOROUGH SHAKING. Tubes are shaken like a rug while limp and loose.



Knocked-Down Type Dustube Collector



Assembled Type Dustube Collector

Assembled Type Dustube Collector equipped with bin hopper and hand shaker

Investigation will prove these tested facts. Write today. *American's* experienced engineers will gladly discuss your particular dust problems with you at your convenience. *Send for Catalog No. 72-B.*

WHEELABRATOR
CORPORATION

(Formerly American Wheelabrator & Equipment Corp.)

812 S. Byrkit Street
Mishawaka, Indiana

PROTECT YOUR WORKERS' HEARING

with

FLENTS*

anti-noise ear stopples

PROMINENT SCIENTISTS SAY:

". . . to keep noise out effectively a plug must completely close the ear canal with an air-tight seal."

". . . there can be no doubt about the primary benefit of ear plugs in noisy locations, provided that they completely occlude the ear canal."

FLENTS are soft balls of wax and cotton that completely seal the ear canal yet permit conversation to be heard. Flents fit any ear canal—no sizes to bother with. And Flents cost so little they may be discarded when soiled.

SOME OF THE MANY FIRMS WHO USE FLENTS:

Allison Division, General Motors
General Electric Co. (16 plants)
Scott Paper Company
United Gas Pipe Line Co.
U. S. Gov't Agencies

Recommended by Liability Insurance companies.

TEST FLENTS in your own plant. Send today for free samples.

ON THE MARKET SINCE 1927

FLENTS PRODUCTS CO., INC. **Dept. A-125, 103 Park Ave., New York 17**

**Reg. U. S. Pat. Off.*

Reg. Trademark

"Solvents Engineered for Safety"

Results Count

Solvent Safety is a Result

STABLE SOLVENTS, PROPERLY USED
ADEQUATELY SUPERVISED AND
CORRECTLY LABELLED ASSURE SOLVENT SAFETY

We Sell Results!

REPRESENTATIVES

Tulsa, Oklahoma
Hodgson Equipment Co.
CHerry 2-9419

Garfield, New Jersey
John A. Campbell
GRegory 2-2640

Pittsburgh, Pa.
Norman M. Gottfried
STerling 1-9165

Ann Arbor, Mich.
Stanley H. Henry
NOrmandy 2-1708

Boston, Mass.
Philip A. Houghton, Inc.
KEnmore 6-8830

Kansas City, Mo.
James B. Schooler Co.
VIctor 0733

Louisville, Ky.
William I. Lightfoot
MAgnolia 6872

Los Angeles, Calif.
Arthur K. Meyer Co.
RIchmond 7-9658

New York, New York
John B. Moore Corp.
Nutley, N. J.
NUtley 2-6666

Far Hills, New Jersey
William R. Parsil
BErnardsville 8-0161

Wilmette, Illinois
Charles C. Searles
WIlmette 5960

Winnipeg, Manitoba, Canada
Donner & Company
92-7986

Export Sales
Hayes, Isham & Company, Inc.
New York, New York
WHitehall 3-5262

WAREHOUSES AND SHIPPING POINTS

Boston, Mass.
Clifton, N.J.
Detroit, Mich.
Harrison, N.J.
Kansas City, Mo.
Lodi, N.J.
Los Angeles, Cal.
Milwaukee, Wis.
Nutley, N.J.
Pittsburgh, Pa.
Princeton, N.J.

JOHN B. MOORE CORPORATION

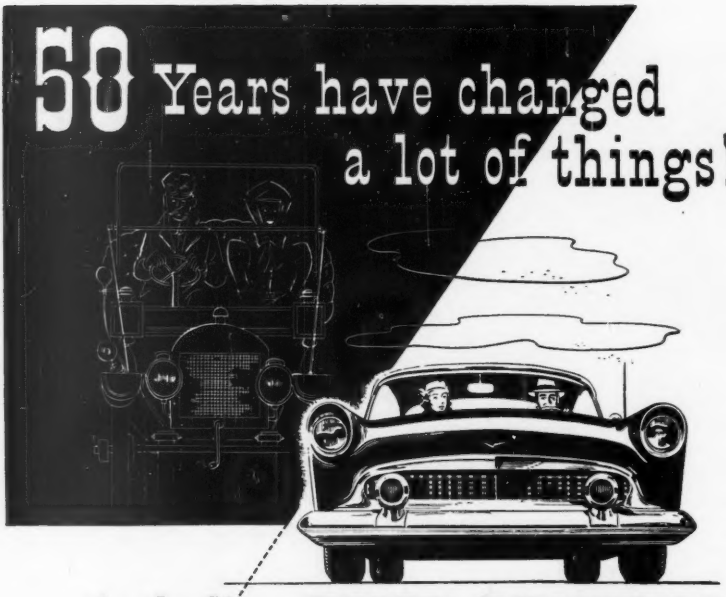
GENERAL OFFICES

Peerless Building, Nutley 10, N.J. NUtley 2-6666

WEST COAST SALES OFFICES

1206 So. Maple Avenue, Los Angeles 15, Calif. RIchmond 7-9658

58 Years have changed a lot of things!



...including DUST CONTROL

OUTSTANDING DAY ADVANTAGES

- 99.99+% Filtering Efficiency
- Up to 5 Times Higher Filtering Rates
- 100 per cent of Equipment Investment Is in Operation at All Times
- Smaller Size with Higher Capacity Saves Valuable Plant Space

Handles 5 times more dust laden air per square foot of cloth than conventional dust filters.

Licensed by H. J. Hersey, Jr.

Diagram of operating design of filter tube. (Available in multiples of 4, 8, 12, 16 & 32)

The automobile has changed America's living habits and the DAY High Pressure Reverse Jet Filter has changed dust control methods. To match the challenge of changing times and changing needs DAY leadership revolutionized the control of dust by utilizing the Hersey principle of filter cloth cleaning with HIGH PRESSURE REVERSE JET AIR. This advanced type of filter handles FIVE TIMES MORE DUST LADEN AIR per square foot of filter cloth than conventional filters.

There is nothing that will match the high on-the-job efficiency provided by DAY filters. It is a proven fact that one DAY filter recommends another. 87% of DAY filter users have ordered additional DAY Reverse Jet Filters.

DAY gives you tremendous savings in valuable plant space, installation and maintenance costs. For maximum filtering results from a minimum filter investment write to DAY for Bulletin 528-R.

The DAY Company

860 Third Ave. N. E. • Minneapolis 13, Minn.

IN CANADA: P. O. Box 70E, Ft. William, Ontario

Branch Plants: Buffalo, Ft. Worth and Toronto, Ontario

Representatives in Principal Cities

DAY SINCE 1881

STOP AIR POLLUTION with DAY DUST CONTROL

type 1551-A
...why this is the Standard
in Sound-Level Meters

Type 1551-A Sound-Level Meter $360.00

Fundamentally, the Type 1551-A Sound-Level Meter consists of a non-directional microphone, a calibrated attenuator, an amplifier, weighting networks to make the amplifier conform with the response of the human ear to pure tones, and an indicating meter.

This instrument's standardization agrees with specifications established by the Acoustical Society of America, the American Standards Association and the American Institute of Electrical Engineers.

Easy To Operate — Sound-level is conveniently indicated by sum of meter and attenuator readings. Meter has accurately readable 16-db scale — adjustable attenuator has range of 100 db in 10-db steps.

Wide Range — Total sound-level range is from 24 db to 140 db above the standard sound-pressure level — Type 1551-P11 Attenuator Pad ($15) plugs into filter jacks extending range upward to 154 db.

Crystal Microphone — Essentially non-directional, Rochelle-salt microphone has good frequency response and sensitivity.

Four Weighting Networks — Three frequency characteristics are available for approximating the response of the ear at sound levels of 40, 70, or 85 db and higher — fourth "20 kc" position provides flat amplifier characteristic from 20 cycles to 20 kc for use in analysis and with wide-range microphones.

Substitute Weighting Networks — Filter jacks permit modification of frequency characteristics by insertion of special weighting networks.

Internal Calibration — Accuracy — "CAL" button permits simple and accurate adjustment of amplifier gain for standardizing instrument sensitivity against any 115-volt a-c power line — upon standardization, accuracy of sound-level measurements is within 1 db for average machinery noises in accordance with A.S.A. standards.

Analysis of Sound Spectrum — Separate amplifier provides low-distortion output for headphones, sound-analyzing or recording equipment. Connections to this jack do not affect panel-meter readings.

Stability — Amplifier is stabilized by inverse feedback — readings are independent (within 1 db) of temperature and humidity over the ranges of room conditions normally encountered.

Meter Damping — Switch damps panel meter for either steady or rapidly fluctuating sound levels — in FAST position, ballistics of meter simulate those of the human ear and agree with A.S.A. standards.

Convenient Automatic ON-OFF Switch — Swivel-mounted microphone folds into panel recess and automatically turns off instrument.

Sturdy Aluminum Case — Light-durable aluminum case is strong, neat, compact, and provides complete shielding. Complete instrument weighs only eleven pounds, with batteries — over-all dimensions are 6¾ x 10¹³⁄₁₆ x 8⅞ inches.

Shock Mounting — Reduces effects of vibration — special tube suspension reduces microphonics.

Batteries Readily Available — Flashlight and portable radio "B" Batteries are used for easy replacement. Four-terminal receptacle for connection to optional a-c power supply permits use of the Type 1262-A Power Supply, $75, in place of batteries, where continuous operation is desired.

Write for the G-R Sound-Measurements Bulletin for Complete Descriptions, Specifications and Prices

ACCESSORIES
for Every Sound Measurement

Additional Microphones

Condenser, Dynamic or ADP Microphones are available for accurate measurement of the higher audio frequencies, to eliminate effects of severe environmental conditions, and for high-level measurements to 200 db.

Narrow and Wide Band Analyzers

Type 760-B Sound Analyzer is best suited to measurement of "pitched" sounds produced by rotating, reciprocating or other cyclic mechanisms where the prevalent frequency components are harmonically related — G-R Type 1550-A Octave-Band Noise Analyzer is designed for rapid, convenient broad-band analysis of sound whose energy is widely distributed over the audio spectrum and is usually caused by shock excitation, impact or turbulence.

Vibration Measurements

A Vibration Pickup and Control Box are available for use with the Sound-Level Meter, converting the latter instrument into an excellent vibration meter.

Convenient Calibration System

Type 1552-B Sound-Level Calibrator permits rapid and reliable calibration of the complete Sound-Level Meter system from microphone to meter — compact Type 1307-A Transistor Oscillator is 400-cycle power source.

GENERAL RADIO Company

275 Massachusetts Avenue, Cambridge 39, Massachusetts, U.S.A.

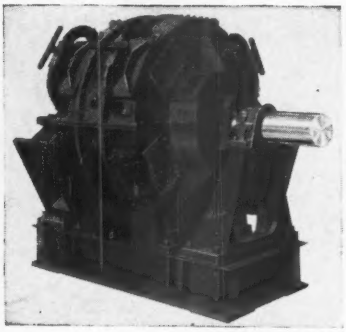
1915-1955

40 Years of Pioneering in Electronics

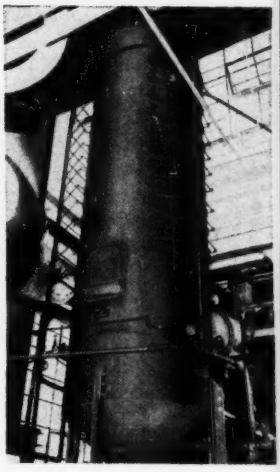
WE SELL DIRECT
Prices are net, FOB Cambridge or West Concord, Mass.

90 West Street NEW YORK 6
8055 13th St., Silver Spring, Md. WASHINGTON, D. C.
1150 York Road, Abington, Pa. PHILADELPHIA
920 S. Michigan Ave. CHICAGO 5
1000 N. Seward St. LOS ANGELES 38

How "BUFFALO" Can Help You with your *AIR CLEANING* Jobs



"Buffalo" Rotary Gas Scrubber



"Buffalo" Hydraulic Scrubbing Tower

With the country becoming more and more pollution-conscious, industry calls on Engineers with many "puzzlers" in the way of air-cleaning problems. Here at "Buffalo", with over half a century of experience in this field — and a wide line of equipment — we are in an excellent position to help. Our files include a tremendous variety of problems successfully solved, with new information being added almost daily. "Buffalo" Engineers are constantly developing highly specialized equipment for new and specialized problems.

EXAMPLE—a collection efficiency of 99.9% plus, ending a serious nuisance problem in phosphate rock drying operations.

EXAMPLE—1000° F. highly corrosive gas effluent made nuisance-free and non-toxic.

EXAMPLE—tar vapor, lampblack, metallic fume in concentrates of 5 to 10 grains/cu. ft. removed to average of .006 grains per cu. ft. in numerous installations.

WRITE FOR BULLETINS AP-225, AP-425, AP 525, 3181-B, and 2424-F.

"Buffalo" equipment includes Air Washers, Hydraulic Scrubbing Towers, Hydro-Volute Scrubbers, Rotary Multi-stage Gas Scrubbers, Gas Absorbers, Blowers, Exhausters and Pumps to solve most any cleaning problem you may have — all engineered to the job, for highest efficiency and simplest possible maintenance. Call on the "Buffalo" Air Engineer in any principal city for sound, helpful recommendations.

"Buffalo" SALES ENGINEER AIR CLEANING

BUFFALO FORGE COMPANY
183 MORTIMER ST. BUFFALO, N. Y.
Publishers of "Fan Engineering" Handbook
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.
Sales Representatives in all Principal Cities

"Buffalo"

Air Cleaning Equipment

Ventilating Air Cleaning Air Tempering Induced Draft Exhausting Forced Draft Cooling Heating Pressure Blowing

M-S-A Model 40 COMBUSTIBLE GAS INDICATOR...

designed specifically for industrial hygiene survey work

Recognizing the industrial hygienist's need for an extra sensitive combustible gas indicator, M-S-A developed the Model 40. This instrument features a dual-range meter. The scales are graduated from 0 to 100% of the lower explosive limit and 0 to 10% of the lower explosive limit. Switching from one range to the other is quickly done with the range switch.

To overcome the effects of humidity variations which have a significant effect on this instrument in the 0 to 10% range, a special sampling hose is provided, thereby eliminating the need for a desiccant.

The Model 40 is compact, light in weight, ruggedly built. Carrying harness aids comfort. The large indicating meter is easy to read.

In addition to the Model 40, there are three other new instruments in the M-S-A Combustible Gas Indicator line. All units are individually calibrated for the particular gases or vapors they are designed to locate and test. Write for complete details.

MSA
SAFETY EQUIPMENT HEADQUARTERS

Call the M-S-A man on your every safety problem
. . . his job is to help you

MINE SAFETY APPLIANCES CO.
201 North Braddock Avenue, Pittsburgh 8, Pa.
At Your Service: 76 Branch Offices in the United States

MINE SAFETY APPLIANCES CO. OF CANADA, LTD.
Toronto, Montreal, Calgary, Edmonton, Winnipeg, Vancouver,
Sydney, N.S. • Representatives in Principal Cities
in Mexico, Central and South America
Cable Address: "MINSAF" Pittsburgh

NOISE METER ANALYZER

particularly convenient, lightweight, portable instruments, rugged, highly accurate, for laboratory and field use.

TYPE 410-C
SOUND LEVEL
METER
$320.00

TYPE 420-A
SOUND
ANALYZER
$619.00

Compensable hearing loss and employee stress reactions such as lower efficiency and morale or increased accident susceptibility are possible effects of unchecked noise. Basic noise measuring and analyzing instruments are the Sound Level Meter and Sound Analyzer.

The 410-C Sound Level Meter and 420-A Sound Analyzer are particularly portable and convenient as well as very rugged and accurate. These instruments meet all applicable specifications of the American Standards Association. Both instruments are powered by readily available hearing-aid batteries designed for long operating life.

The Type 410-C Sound Level Meter measures overall intensities of noise and sound from 34 db to 140 db. This miniature sound level meter has received the "Electrical Manufacturing" Award for outstanding achievement in product, development, design and engineering.

The 420-A Sound Analyzer separates overall noise and sound levels into their component frequency bands. The analyzer has high and low-pass filters which may be independently adjusted in half-octave steps. A simple interlock allows the passband width to be fixed in any multiple of one-half octave.

Both instruments are readily used by non-technical personnel with a minimum of training. Please write us for complete details on these instruments and their accessories. ...

FREE NOISE BOOKLET "TRICKS OF THE TRADE" Instruments, Measurement, Control

HERMON HOSMER SCOTT, INC.

"PACKAGED ENGINEERING"

385 PUTNAM AVE. • CAMBRIDGE 39, MASS.

EXPORT DEPT. 13 E. 40th ST. NEW YORK 16, N. Y. U.S.A.

"Look! It soaks up grease just like a sponge."

LAN-O-KLEEN removes 95% of all dirt and grime encountered in industry.

Easily — and safely!

LAN-O-KLEEN helps to protect the skin as it cleans. WEST — *in pioneering the development of "double action" industrial cleaners* — was the first to impregnate *beneficial amounts* of free lanolin into a corn meal type hand cleaner.

LAN-O-KLEEN is economical to use. It bulks greater than most other hand cleaners — *therefore goes farther per pound.* Too, the sturdy LAN-O-KLEEN dispenser rations just the right amount to do a thorough cleansing job.

LAN-O-KLEEN is one of a group of WEST products formulated for the prevention and control of industrial dermatitis. Workers' hands are their most valuable tools. By helping to prevent dermatitis, you can help keep costs down — *by keeping workers on the job at maximum efficiency.*

A specially trained WEST representative will gladly tell you more about LAN-O-KLEEN and the other products used in the WEST Dermatitis Control Plan. Just write or call your local WEST office.

ND LARGEST
OF ITS KIND
ORLD

75th
EST DISINFECTING Company
NIVERSARY

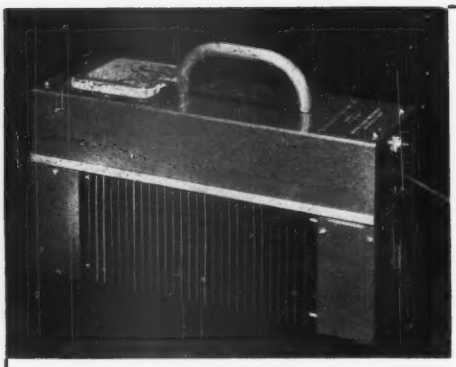
FREE BOOKLET

Use your business letterhead to request our 24 page booklet
"The Control of Dermatitis in Industry."

WEST DISINFECTING COMPANY

Dept. AH, 42-16 West St. Long Island City 1, N. Y.

Branches in Principal Cities — In Canada, 5621-23 Cassin



MERCURY VAPOR METERS

RANGES	0.005 to 0.1 and 0.03 to 3 mg./cu. m.
SIZE	13x8½x4½ inches
WEIGHT	5 to 8 lbs.
PRICE	from $195

Three different models are available with features of low cost, high sensitivity or an alarm. These are instantaneous indicating, photoelectric type instruments, with meters calibrated in mercury concentrations for quick indication. Literature sent on request.

Write for a bibliography on the hazards of mercury vapor.

HAROLD KRUGER INSTRUMENTS

P. O. Box 164 **San Gabriel, California**

HOW'S YOUR *HEALTH?*

Check Turco's Big Three for More Certain Plant Safety

Whatever your cleaning problem, Turco has a compound to do the job *safer*, faster, better. Shown here are three of the many Turco materials that produce safer, more efficient plant operation.

Three good reasons why America's *safety-conscious* plants turn to Turco... *first!*

TURCO PRODUCTS, INC.
Chemical Processing Compounds
6135 S. Central Ave. • Los Angeles 1, Calif.
FACTORIES: Newark • Chicago • Houston • Los Angeles

1

OILIFT
For grease-free, **non-slip** concrete floors the **safe**, easy way. Eliminates fire hazards. Contains no caustics or acids. Offers maximum personnel safety. Easy to use, Oilift does the work **chemically.**

2

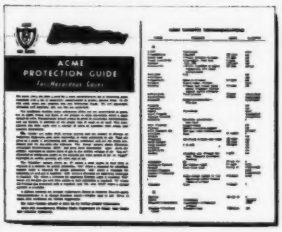
TURCO-SOLV
Safety solvent to replace dangerous carbon tet in cleaning operations. Nonflammable, nonconductive, fast-drying. Leaves no residue. Especially effective for in-place cleaning of motors, generators, etc.

3

HANDISAN
Complexion-quality mechanics hand soap. Gets grime **gently.** Nonchapping, nonclogging, free rinsing. Assures better handwashing at lower cost per worker. Available with or without lanolin.

67 SPECIALIZED SERVICE CENTERS—From coast to coast and border to border, Turco specialists and Turco warehouses are in most principal cities. Consult your local classified phone book for the one nearest you.

433 GAS HAZARDS
...And How to Overcome Them!



As a practical help to industrial hygienists, ACME offers this valuable Protection Guide which lists 433 hazardous gases, mists, fumes and dusts—along with the ACME gas mask equipment designed to give you dependable protection for each specific hazard. This vital information, available through ACME exclusively, is a must if you have any hazardous condition of this type in your plant. Write for your free copy today.

ACME...
the Only Gas Mask with the "Picture Windows"

You never have that "jammed-in" feeling with the ACME Full-Vision gas mask. Its patented larger lenses give you full, natural vision with greater comfort as well as protection. Other features include easier breathing, less fogging and increased audibility. There's an ACME Mask to provide the right protection for every hazard listed in the Protection Guide. Write for Bulletin 541 describing ACME canister gas mask equipment. Other types also available.

ACME PROTECTION EQUIPMENT COMPANY
1245 Kalamazoo Street, South Haven, Mich.

Reduce the Hazards of Mercury Poisoning
with

HgX

A Mercury Decontaminent

Write for descriptive folder

STIEH CHEMICALS

William M. Stieh and Co., Inc.
20 Vesey Street • New York 7, N. Y.

NEW! ADDRESS... EQUIPMENT... FACILITIES

BUT THE SAME — *FAST ACCURATE ECONOMICAL*

LABORATORY SERVICES

PRODUCT DEVELOPMENT	Toxicology
NEW DRUG APPLICATIONS	Bacteriology
CONSULTATION	Pharmacology
FDA-FTC COUNSEL	Nutrition
LABELS AND BROCHURES	Biochemistry
	Chemistry

Write for schedule

SCIENTIFIC ASSOCIATES
3755 Forest Park Boulevard
St. Louis 8, Missouri
Telephone: JEfferson 1-5922

J. WILLIAM FEHNEL, Consultant
30 years experience in
INDUSTRIAL HEALTH, AIR AND STREAM POLLUTION PROBLEMS

P. O. Box 172 Central Station
Jamaica 35, New York
Telephone: JAmaica 9-2438

Phone CApitol 7-5708

211 MILBY STREET
HOUSTON 3, TEXAS

OCCUPATIONAL HEALTH LABORATORIES

Dithizone method for lead. Urinary coproporphyrin

Phone CApitol 7-5708

INDUSTRIAL HEALTH
•
HYGIENE AND SAFETY SERVICE

6432 Cass Avenue, Detroit, Michigan
Trinity 1-4812
and
903 East Lincoln Ave., Royal Oak, Mich.
Lincoln 2-9569

GORDON C. HARROLD, PH.D.
STUART F. MEEK, M.D.
AND ASSOCIATES

EMERSON VENABLE, P.E.
CHEMIST AND ENGINEER
Fellow, American Public Health Assoc.

CONSULTANT
IN
Air Pollution, Chemical Warfare and Industrial Hygiene—Research

PHONE Hi-land 1-8045
6111 FIFTH AVENUE PITTSBURGH 32, PA.

MODEL NW-222

A PUMP OF MANY USES
TO THE
INDUSTRIAL HYGIENIST

This small pump provides an excellent source of suction for operating impingers, bubblers, impactors and other air sampling devices. It can be readily assembled with these to make compact, complete sampling units. 10 Day Free Trial.

LIGHTWEIGHT—4¼ lbs.
EFFICIENT—22 lpm free air
—17 lpm @ 3" Hg
DEPENDABLE

SMALL SIZE—3½" x 6" base
VERSATILE—also provides source of vacuum (22" Hg) and pressure (14-17 psi)

JORDAN PUMP CO.
P.O. Box 94, Station A Atlanta, Ga.

Complete DUST CONTROL AND VENTILATION FOR FOUNDRIES

Dust control, ventilation and disposal systems for the modern foundry—large or small—are designed for top efficiency and economy by Schneible engineers. Standard Multi-Wash collectors and auxiliary dust control equipment are available for sand dryers, shakeouts, core knockouts, casting cleaning operations, and grinding.

Schneible ventilation and exhaust systems provide dust, smoke and fume control for pouring, mold cooling, mold spraying and casting removal stations.

CLAUDE B. SCHNEIBLE COMPANY
P. O. Box 81, North End Station Detroit 2, Michigan

EUROPEAN LICENSEE: ELEX S. A., ZURICH, SWITZERLAND
CABLE ADDRESS FOR FOREIGN INQUIRIES: CBSCO

PRODUCTS

Multi-Wash Collectors • Uni-Flo Standard Hoods • Uni-Flo Compensating Hoods • Uni-Flo Fractionating Hoods • Water Curtain Cupola Collectors • Ductwork • Velocitrap • Dust Separators • Entrainment Separators • Settling and Dewatering Tanks • "Wear Proof" Centrifugal Slurry Pumps

Send for your copy of bulletins 610; 47; 450; 353 and 246 covering Schneible dust control equipment

FOUNDRY EQUIPMENT MANUFACTURERS ASSOCIATION INC. MEMBER FEMA

SCHNEIBLE

ENGINEERING REPRESENTATIVES IN PRINCIPAL CITIES

Now compare these facts about

IT GUARDS WHILE IT CLEANS

WATERLESS HAND CLEANER *with any other product*

1 Can be rinsed with water – no soap necessary.

2 Does not leave sticky or oily residue on hands.

3 Contains no ammonia, halogenated or aromatic (ring) solvents.

4 No free alkali – pH 7.

5 Contains lanolin.

6 Temperature tolerance without separation or melting from 0°F to 140°F.

7 Fast liquification on application.

8 No dehydration of skin—leaves hands soft and smooth.

9 Protects natural acid mantle of skin (pH 6).

10 Guaranteed satisfactory performance comparable to other PLY Products backed by 25 years of experience.

AVAILABLE IN
• POUNDS
• QUARTS
• GALLONS
•

YOU PAY NO PREMIUM PRICE FOR PLY QUALITY

– ESTABLISHED 1933 –

MILBURN COMPANY DETROIT 7, MICHIGAN

– MANUFACTURERS OF –

PLY SKIN PROTECTION – PLYGLOV PLASTIC COATED GLOVES

PLY GARB CHEMICAL RESISTANT CLOTHING